State of Connecticut.

PUBLIC DOCUMENT No. 34.

FOURTEENTH ANNUAL REPORT

—OF THE—

STORRS

AGRICULTURAL EXPERIMENT STATION,

STORRS, CONN.

1901.

PRINTED BY ORDER OF THE LEGISLATURE.

MIDDLETOWN, CONN.:
PELTON & KING, PRINTERS AND BOOKBINDERS.
1902.

OFFICERS OF THE STATION.

Executive Committee.

G. A. Hopson, G. S. Palmer, B. C. Patterson.

Treasurer.

William D. Holman, West Willington.

Station Staff.

W. O. Atwater,	*Director.*
C. S. Phelps,	*Vice-Director and Agriculturist.*
F. E. Singleton,	*Secretary.*
H. W. Conn,	*Bacteriologist.*
W. A. Stocking, Jr.,	*Dairy Experimenter.*
A. P. Bryant,	*Chemist.*
R. D. Milner,	*Chemist.*
W. M. Esten,	*Assistant in Dairy Bacteriology.*

The Station is located at Mansfield (P. O. Storrs), as a department of the Connecticut Agricultural College. The chemical and other more abstract research is carried out at Wesleyan University, Middletown, where the Director may be addressed.

CONTENTS.

Report of the Executive Committee.

To His Excellency George P. McLean,

Governor of Connecticut:

In accordance with the resolution of the General Assembly concerning the congressional appropriations to the Agricultural Experiment Stations, and an Act of the General Assembly approved March 19, 1895, relating to the publication of the Reports of the Storrs Agricultural Experiment Station, we have the honor to present herewith the Fourteenth Annual Report of that Station, namely, that for the year 1901.

The accompanying report of the Treasurer gives the details of receipts and expenditures. We refer you to the report of the Director and his associates for a statement of the work accomplished during the past year.

Respectfully submitted,

GEORGE A. HOPSON,
B. C. PATTERSON,
GEORGE S. PALMER,
Executive Committee.

Report of the Treasurer

For the Fiscal Year Ending June 30th, 1901.

The following summary of receipts and expenditures, made out in accordance with the form recommended by the United States Department of Agriculture, includes, first, the Government appropriation of $7,500, and, secondly, the annual appropriation of $1,800 made by the State of Connecticut, together with various supplemental receipts. These accounts have been duly audited according to law, as is shown by the Auditors' certificates, copies of which are appended.

GOVERNMENT APPROPRIATION—RECEIPTS AND EXPENDITURES.

RECEIPTS.	
United States Treasury,	$7,500 00
EXPENDITURES.	
Salaries,	4,091 08
Labor,	1,057 53
Publications,	76 78
Postage and stationery	336 13
Freight and express,	96 45
Heat, light and water,	627 36
Chemical supplies,	220 98
Seeds, plants and sundry supplies,	190 20
Fertilizers,	64 23
Feeding stuffs,	133 34
Tools, implements and machinery,	5 05
Furniture and fixtures,	59 20
Scientific apparatus,	355 89
Live stock,	25 15
Traveling expenses,	141 48
Contingent expenses,	10 00
Buildings and repairs,	9 15
	$7,500 00

AUDITORS' CERTIFICATE.

We, the undersigned, duly appointed Auditors of the Corporation, do hereby certify that we have examined the books and accounts of the Storrs Agricultural Experiment Station for the fiscal year ending June 30, 1901; that we have found the same well kept and classified as above, and that the receipts for the year from the Treasurer of the United States are shown to have been $7,500, and the corresponding disbursements $7,500; for all of which proper vouchers are on file and have been by us examined and found correct, thus leaving no balance.

And we further certify that the expenditures have been solely for the purposes set forth in the act of Congress, approved March 2, 1887.

(Signed,) Geo. A. Hopson, M. M. Frisbie, } *Auditors.*

Hartford, Conn., Aug. 10, 1901.

STATE APPROPRIATION AND SUPPLEMENTAL RECEIPTS—RECEIPTS AND EXPENDITURES.

RECEIPTS.

State of Connecticut,	$1,800 00
Miscellaneous receipts,	128 20
	$1,928 20

EXPENDITURES.

Salaries,	$729 96
Labor,	195 63
Postage and stationery,	20 49
Freight and express,	7 82
Heat, light and water,	174 89
Chemical supplies,	2 50
Seeds, plants and sundry supplies,	87 93
Bacteriological investigations,	530 07
Feeding stuffs,	15 90
Tools, implements and machinery,	4 86
Furniture and fixtures,	17 79
Scientific apparatus,	139 26
Traveling expenses,	1 10
	$1,928 20

AUDITORS' CERTIFICATES.

We, the undersigned, duly appointed Auditors of the Corporation, do hereby certify that we have examined the books and accounts of the Storrs Agricultural Experiment Station for the fiscal year ending June 30, 1901; that we have found the same well kept and classified as above, and that the receipts for the year from the Treasurer of the State of Connecticut are shown to have been $1.800, and the corresponding disbursements $1,800, for all of which proper vouchers are on file and have been by us examined and found correct; thus leaving no balance.

(Signed,) GEO. A. HOPSON, M. M. FRISBIE, } *Auditors.*

HARTFORD, CONN., Aug. 10, 1901.

We, the undersigned, duly appointed Auditors of the Corporation, do hereby certify that we have examined the books and accounts of the Storrs Agricultural Experiment Station for the fiscal year ending June 30, 1901; that we have found the same well kept and classified as above, and that the receipts for the year from miscellaneous sources are shown to have been $128.20, and the corresponding disbursements $128.20; for all of which proper vouchers are on file and have been by us examined and found correct, thus leaving no balance.

(Signed), GEO. A. HOPSON, M. M. FRISBIE, } *Auditors.*

HARTFORD, CONN., Aug. 10, 1901.

W. D. HOLMAN, *Treasurer.*

Report of the Director for the Year 1901.

The work of the Storrs Station during the year 1901 has been largely in continuation of that of previous years. This is in accordance with the policy of the Station since its establishment, namely; to concentrate its energies upon a few important lines of inquiry and to continue on these from year to year as long as circumstances warrant. The principal inquiries now in progress at the Station have to do with the nutrition of plants, domestic animals, and man, and the bacteriology of the dairy. These have included experiments on the effects of fertilizers upon the growth and composition of plants, studies of the rations fed to milch cows, studies of bacteria, especially those concerned in normal cream ripening, and investigations on the food and nutrition of man. Some account of the objects, methods and results of various inquiries in these lines are given by different members of the Station staff in this Report. Not all the work done during the year is described in the present volume, since in some cases the results are not yet ripe for publication; on the other hand, some of the articles include the results of the work of more than a year.

FIELD AND POT EXPERIMENTS WITH FERTILIZERS.

The experiments on the effects of fertilizers upon the growth and the composition of plants were carried on in 1901 as in previous years at Storrs, under the direction of Prof. Phelps. These include soil tests and soil improvement experiments on field plots, and special nitrogen experiments both on field plots and in pots. Accounts of the experiments of the past year are given by Prof. Phelps in this Report.

Soil tests.—The experiment known as soil test has been continued at Storrs for twelve years upon the same field. The field is divided into parallel plots of equal size, on which fertilizers containing nitrogen, phosphoric acid and potash are applied singly and in different combinations, and corn, potatoes,

oats and cow peas or soy beans are grown in a four-year rotation. The object of the experiment is to study the capacity of the soil to supply the fertilizing ingredients mentioned, and the particular needs of the crops for any or all of them. The experiment of 1901 was with soy beans. The deduction from the results of this test are in accord with those of previous years. From the results obtained during the twelve years of experimenting in this particular field, it appears that the fertilizing ingredients most needed have varied with the crop; that is to say, the peculiarities of the plant have had as much or more to do with deciding the demand for fertilizers than any special deficiency of the soil. Cow peas and soy beans have been benefited by phosphoric acid and potash, but have paid little heed to nitrogen. Corn and oats have responded well to nitrogen, and both have been helped by phosphoric acid, but neither has been much increased by potash. Potatoes have been benefited by all three ingredients, and especially helped by potash.

Special nitrogen experiment.—The object of these experiments is to obtain information regarding the effects of nitrogen in different fertilizers upon the yield, and more especially the composition of different crops. In carrying out these experiments the crops are grown on a series of parallel plots some of which are without fertilizer, some with definite quantities of mineral fertilizers only, and others with the mineral fertilizers and varying quantities of nitrogen. The effect of the nitrogen upon the total yield of the crop is estimated by comparing the yields from the plots having the mineral fertilizers alone with those from the plots having different quantities of nitrogen in addition to the minerals; the effect upon the composition of the crop is likewise estimated by analyzing samples of the crops from the different plots. These experiments are made each year with corn, cow peas and soy beans, that of 1901 being the seventh in a consecutive series on the same plots. The results of the seven years of experiment with these three crops indicate that with the cereals, the effect of the nitrogenous fertilizer is to increase both the total yield of the crop and the proportion of protein, thus in a two-fold way increasing the food value; while with the legumes the nitrogen of the fertilizers has very little effect upon either

the yield or the composition. The effect of the nitrogenous fertilizers upon the yields of the crops has long been known. The principle which has been less thoroughly understood, and which these experiments are bringing out more clearly, is that not only the total amount of the crop, but also the percentage of its costliest ingredient, protein, may be increased. In this respect particularly the results of the experiments are of immense practical importance to farmers, in indicating how the production of protein on the farm may be increased.

Pot experiments with fertilizers.—Experiments similar to the special nitrogen experiments on the field plots have been carried on for a few years on a small scale in such a way that moisture and other external conditions affecting the growth of the plants might be more completely under control. In these experiments the plants are grown in pots filled with soil quite uniformly mixed, and treated with the same kinds of fertilizers as are used in the plot experiments. The results of these experiments accord with those of the special nitrogen field experiments in indicating that the nitrogenous fertilizers are valuable for increasing the quantity and protein content of grasses and grains, but are of little value for the legumes.

Experiment on soil improvement.—The purpose of this experiment is to study the economy of different methods of manuring for restoring fertility to a soil lacking in organic matter and in available nitrogen. The experiment was begun in 1899 and has since been continued on the same plots. The results thus far obtained indicate a high value for legumes like common red clover when plowed under for green manuring.

FEEDING EXPERIMENTS WITH DAIRY HERDS.

Studies of rations fed to milch cows were carried on during the past year as in preceding years, in coöperation with a number of farmers in different parts of the State. A report of the studies of four herds is given by Prof. Phelps in the present Report. The object of these experiments is to learn how representative dairy farmers in Connecticut feed their cows, compare the results obtained by their methods with results of other methods elsewhere, and to suggest improvements wherever they can be made. Besides serving for instruction to the

farmers in methods of scientific study, the coöperative experiments bring new and valuable information regarding the economical feeding of cows for the production of milk and butter. The results of the experiments point to the value of rations with a narrow nutritive ratio, that is with liberal proportions of protein, for the production of milk and butter; and wherever a wide ration has been found in use an increase in the amount of nitrogenous feeding stuffs has been proposed, usually with profitable results so far as the short experiments have indicated. It is encouraging to observe that dairy farmers are becoming more and more familiar with such facts, a number of farmers having been found who were feeding rations with narrow ratio and large quantities of protein.

DAIRY BACTERIOLOGY.

The work upon the bacteria of milk has been continued during the present year by Prof. Conn, aided by Mr. Esten, at Wesleyan University. Mr. W. A. Stocking has also been employed by the Station and his whole time devoted to carrying on the experiments in dairy bacteriology at Storrs. The experiments conducted by Prof. Conn and his associates during the past two or three years are in a new field of inquiry. The topics that have been investigated are the sources of bacterial contamination of milk in ordinary dairying and the practical methods of reducing this contamination, and the question of the growth of bacteria in milk under normal conditions. The latter subject has a very practical bearing upon problems associated with the healthfulness of milk and with the ripening of cream and cheese. It is hoped that the results of the experiments will ultimately give to dairymen a more satisfactory explanation of the relation of the different species of bacteria to the quality of their products. The results which are given in this Report afford interesting suggestions regarding the dairyman's methods of handling bacteriological problems in the future. Perhaps the most significant is the suggestion that the lactic bacteria are rather an advantage than a disadvantage to the dairyman since they protect the milk, cream and cheese from the action of other bacteria.

FOOD AND NUTRITION OF MAN.

The inquiries on the food and nutrition of man carried on by the Station in coöperation with the United States Department of Agriculture for several years past have been continued. These include analyses of food materials, studies of dietaries of different classes of people, digestion experiments with men, determinations of the fuel values of food materials, and metabolism experiments with men in the respiration calorimeter. With the exception of the dietary studies, investigations in each of these lines have been made during the past year. The determinations of the composition, digestibility, and fuel values of food materials were made in connection with the metabolism experiments with men in the respiration calorimeter. Six metabolism experiments were made during the past year, accounts of which will be published later. The results of a large number of experiments upon the digestibility of food materials are given in the present Report.

ANALYSES OF FOODS, FEEDING STUFFS, ETC.

In connection with the inquiries of the Station, a large number of chemical analyses are required. These include analyses of crops grown in the tests with fertilizers, and of foods and other materials used in the metabolism experiments with man.

In addition to the chemical analyses of the various foods, feeding stuffs, etc., the heats of combustion of a large number of specimens have also been determined.

METEOROLOGICAL OBSERVATIONS.

The usual observations of temperature, barometic pressure, wind velocity, humidity and precipitation have been made at Storrs. In addition, records of rainfall during the growing season have been made in other places in different parts of the State by farmers who have coöperated with the Station.

DISSEMINATION OF INFORMATION.

Considerable attention is given to the dissemination of the results of the work of the Station. Annual Reports and Bulletins are published and distributed throughout the State and elsewhere. The Reports contain the more technical details of

the investigations for permanent record and for the especial use of those particularly interested in such matters, while the Bulletins are of a more popular nature and present the practical side of the results of the work. The latter are printed in larger numbers than the former.

The Station has also an extensive correspondence, letters being written in answer to questions concerning the work which come not only from Connecticut and other parts of the United States, but also from foreign countries. In addition to this, members of the Station staff have given frequent lectures and addresses before institutes, conventions, and other meetings of farmers and dairymen.

W. O. ATWATER, *Director.*

THE COMPARATIVE GROWTH OF DIFFERENT SPECIES OF BACTERIA IN NORMAL MILK.

BY H. W. CONN AND W. M. ESTEN.

The study of the bacteria in milk carried on during the last fifteen years has been confined largely to two lines of inquiry. (1) There has been a large amount of quantitative bacteriological study, determining the number of bacteria in milk under different conditions; and (2) there has been a large amount of work done in separating from milk different species of micro-organisms and carefully studying their biological characters. This has continued until there are described in literature more than 200 species of bacteria more or less characteristic of milk or some of its products. Although this work has continued in very large amount for many years, the information which has been obtained in regard to the actual species of bacteria in milk under different conditions, is very slight indeed. Very little attention has been given to the growth of different species of bacteria under normal conditions. De Freudenreich,* Russell and Winzirl,† and Harrison,‡ have carried on some such studies in regard to the bacteria present in cheese during the period of ripening, resulting in some considerable change in the belief of scientists as to the real nature of the ripening process in cheese. Practically nothing, however, has hitherto been known of the development of different species of bacteria in normal milk. The increase in numbers has been determined in scores of cases, but no studies have been made upon the question as to whether this increase, occurring as the milk ages, is an increase in all kinds of dairy bacteria, or whether it is only certain species that thus develop at the expense of others.

* Centbl. f. Bact. u. Par. II., III., 1897.
† Wisconsin Exp. Sta. Rept., 1896.
‡ Harrison, Trans. Can. Inst., 1901, VII.

A better knowledge of the actual growth of bacteria in milk under normal conditions would be useful in at least three different directions.

1. The general biological laws which control living things are materially concerned in such a problem. It is clear enough that there must be going on in the milk, for the first day or two after it has been drawn from the cow, an intense bacteriological struggle. The different species of bacteria are endeavoring to adapt themselves to the conditions, and there is a "struggle for existence" among them, the conclusion of which is a matter of much importance in its bearing upon general biological laws.

2. The value of such a knowledge to the dairy industry would doubtless be very great, although in advance it is quite impossible to predict just what its practical use might be. It would show what species are likely to disappear in the struggle for existence. It might perhaps give us information in regard to the conditions which would be required for checking the growth of undesirable organisms, and favoring the growth of desirable organisms. It might give practical results bearing upon the problem of controlling the bacteria of the milk supply as well as upon problems connected with cream ripening. The lack of knowledge in regard to the real growth of bacteria in milk and cream under normal conditions is doubtless one reason why we have hitherto not been able to solve successfully the problem of artificial cream ripening.

3. The healthfulness of milk is very closely associated with the problem of the growth of bacteria. It is a general belief that a warm summer temperature renders milk a dangerous article of food, especially for children, and that this is because the warm temperature stimulates the growth of bacteria. It has been consequently assumed, without any proof for the assumption, that the wholesomeness of milk can be determined by the number of bacteria which are present. But there are, however, rapidly increasing reasons for believing that this does not express the whole case. It is not simply the number of bacteria in milk which is concerned in the wholesomeness of the milk. Milk containing large numbers of bacteria has been found to be healthful; and it is quite certain that milk might contain only small numbers of bacteria but would be

decidedly injurious if these small numbers were pathogenic types. We have shown in previous work* that in cream which is a few hours old the large proportion of the bacteria present are lactic organisms, so large a proportion that the lactic bacteria are sometimes regarded as the normal bacteria of milk. There is at the present time much evidence for believing that the lactic bacteria, so far from being a detriment to the wholesomeness of the milk, are really advantageous. It is true that they cause the milk to sour if they become too abundant; but the acid that they produce in milk protects the milk from other fermentations which are probably more injurious. It is very probable that putrefactive changes which take place in milk if the lactic organisms are not present are more injurious to health than the development of lactic acid. Lactic acid in itself is not injurious in small quantities, and there is no reason for believing that the presence of lactic bacteria in milk, even in considerable numbers, will, to any appreciable extent, detract from the healthfulness of the milk. On the other hand, there is good reason for believing that the putrefactive changes in milk which other types of bacteria produce, if they have an opportunity of developing therein, will be quite likely to result in intestinal disturbances. It is at least a probability that much of the diarrhœal disturbance in children is due to the putrefactive fermentation of milk, and it is almost certain that these are not due primarily to lactic bacteria. Indeed, it has been shown by Bienstock† that the lactic bacteria are probably useful in the intestine. If they are absent from the intestines of animals the intestinal contents are quite sure to undergo an offensive putrefactive fermentation, while the presence of either lactic bacteria or the common *B. coli* prevents the putrefactive condition of intestinal digestion. These experiments of Bienstock have not as yet been confirmed, but they are quite in accordance with the general conclusion which has been reached by several observers, that the presence of lactic organisms in milk prevents putrefactive fermentation, and that these bacteria should therefore be looked upon as a protection to the milk from the standpoint of its wholesomeness, rather than as injurious in their action.

---

* Storrs Expt. Sta. Rept. 1900.

† An. d. l. Inst. Past. XIV. p. 750.

If these facts are true it follows that the study of the development of the species of bacteria in milk is a matter likely to be of great importance in giving data for determining the wholesomeness of milk, and any facts which can be given bearing upon this general subject will be contributions toward the solution of problems connected with the use of milk.

The reason that such studies have not been hitherto carried out is doubtless chiefly the difficulty of the study. To make a quantitative test of bacteria in milk is very easy, but to determine what species are present is much more difficult and requires a long study of each individual sample; and to determine the percentage of each species present in the whole sample of milk has been hitherto practically an impossibility. The only method that can be used is that of making ordinary bacteriological plates and then carefully counting colonies on the plates. It is well known to all bacteriologists that, whereas it is possible by study of such plates to differentiate certain species of bacteria from each other, a complete differentiation is quite impossible. Many species of bacteria produce colonies upon gelatin plates which are so closely alike that they cannot be distinguished, and thus it is quite impossible to determine what proportion of all bacteria present may belong to one species and what proportion to another. The difficulties of such a line of study have been so great that it has never been followed beyond the differentiation of a few simple characteristic types. De Freudenreich, Russell and Winzirl, and Harrison, have studied the proportion of lactic bacteria in cheese, and Jensen* has in a similar way made estimations of the number of a few species of organisms present in butter. But beyond some slight differentiation of a few characteristic forms, no work of this kind has hitherto been attempted.

In the laboratory at Wesleyan University there has been developed during the last three or four years a method of studying milk bacteria which enables us to make a moderately satisfactory differentiation of species from each other. This method, which was devised several years ago, has been in constant use in our work, and the more it has been used the more we have been convinced that it enables us to separate species from each other in a manner superior to that in which

*Centbl. f. Bact. u. Par. II., VIII., 1902, p. 11.

it can be done by any other method yet described. It has required several years for us to learn to understand the results so as to work with a considerable degree of satisfaction, and even yet we are only able to get an approximation toward a complete analysis. Experience, however, has enabled us to distinguish with considerable accuracy the colonies produced upon gelatin plates by all, or at least most, of the more common milk bacteria.

METHOD OF EXPERIMENTATION.

The method that has been adopted in this laboratory is based upon the use of a gelatin culture medium to which has been added a certain amount of litmus. This culture medium has already been described, but its careful preparation is so important for a proper differentiation of species that a description of the method of preparing it is here given.

Preparation of litmus-sugar-gelatin.—The culture medium which we use is made as follows:

1.	Water, - - -	500 cc.
	Peptone, - - -	10 grams.
	Milk sugar, - -	30 grams.
	Gelatin, - - -	120 grams.
	Liebig's extract of beef,	5 grams.

The amount of milk sugar added is about 3 per cent. of the solution finally prepared. The purpose of this is to obtain as closely as practicable the conditions in milk. We use Liebig's extract of beef rather than the juice of chopped beef, because our experience has indicated that, for our purpose, this is perfectly satisfactory, and its use is much simpler, requiring less time and trouble.

The materials are placed together in a dish and dissolved by heating at a temperature below 60° C. to make a solution which, as will be seen, contains twice the quantity of the various ingredients that is contained in the ordinary gelatin culture media. After the material has become thoroughly dissolved we neutralize the solution directly, by use of NaOH solution, testing the material for neutralization with litmus rather than phenolthalein. We use red and blue litmus papers made in our laboratory and which are especially delicate, and we add

NaOH to the solution until the material is in the very faintest degree alkaline. In other words, we add just enough NaOH to pass the neutral point, as shown by its action upon red and blue litmus papers.

After the neutralization we add the white of an egg and boil for three-quarters of an hour. In this boiling we make use of a 50 per cent. solution of calcium chloride, which boils at about 112° C. Placing the dish containing the gelatin solution in a bath of this mixture we can leave the material to boil over a moderate gas flame without danger of burning; considerable care is necessary, however, to regulate the gas flame so that the solution does not boil over.

2.	Water, - - -	500 cc.
	Dry litmus (in cubes),	48 grams.

The litmus is steeped in the water for three hours or more at a temperature of about 60° C. to dissolve as much of the active material as possible. The solution is then filtered.

After solution 1 has boiled with the white of an egg for three-quarters of an hour it is mixed with the filtered litmus solution 2, the two together making the bulk up to about a liter, and water is added if necessary to replace the water which has been evaporated. The solution is then warmed slightly, though not above 60°, in order to avoid as much as possible the changes in the litmus which high temperatures produce. The solution is then filtered through absorbent cotton, distributed in sterilized tubes, about 8 cc. in each, and is ready for final sterilization, which is carried on as usual by steaming on three successive days. The sterilization always has a tendency to change the color of the litmus to a reddish brown, but the blue color is restored after the litmus cools and stands for a few hours in contact with the air. When finally sterilized and cooled the solution should be a deep blue color, so that when poured out into petri dishes the color is quite strong. We have found that the litmus of commerce is quite variable in strength, since 3 per cent. of litmus (30 grams) is sometimes sufficient to give the required blue color, while in other cases it requires 40–50 grams. We have found that as a rule 48 grams produces as good a color as can be desired, but sometimes, if the litmus is exceptionally strong, a smaller

amount is preferable. We find it advantageous to buy the dry litmus in rather large quantities, and then after a single experiment has shown us the amount of litmus of the particular sample that is needed to produce the desired color, we continue to use the same percentage until the whole quantity of litmus has been used. A new sample of litmus will require a new percentage.

This culture medium is used exactly as ordinary gelatin. The milk to be studied is diluted in sterilized water to the desired amount, and a cubic centimeter of the final dilution is added to a test tube containing a definite quantity of the sterilized litmus gelatin. The material is poured into petri dishes, hardened, and set aside at ordinary temperature for development. In actual use we endeavor so to dilute our milk that the plates which we obtain will have from a hundred to a thousand colonies each. If more than a thousand are present on a plate it is almost impossible satisfactorily to differentiate the colonies from each other and to determine their species. If less than a hundred are present, while the differentiation of species is very satisfactory, we do not think that the sample gives as close average results as when the number is larger. A plate containing two or three hundred is the most satisfactory. It is of course not possible in all cases to regulate the dilutions so that the plates shall have the proper number of colonies. Only long experience with the milk under conditions of experiment enable us to determine this accurately, and as will be seen in the following experiments, even long experience is sometimes at fault. It frequently happens that two samples of milk under identical conditions show very great differences in the number of bacteria, and no rule as to the amount of dilution can be applied to the two samples and give the same results with certainty. The determination of the proper dilution of the milk is one of the most difficult problems in the experiments.

In order to differentiate the colonies and determine from their study the species of bacteria present, it is necessary that the plates should be allowed to grow several days before examination. The study of the plates when they are two days old will enable one readily enough to count the number of bacteria, but not properly to differentiate the species. The same plate when

four or five days old shows a differentiation which is clear and sharp, so that it is possible to determine, not only the total number, but approximately the number of each kind of bacteria. Plates that are older than these are even more useful, because the colonies become more and more distinct in their characteristics the older they grow.

This necessity of keeping the plates until they are several days old introduces the most serious fault of our method of study. The presence of liquefying bacteria is sometimes quite fatal to the success of an experiment. If a sample of milk chances to contain a considerable number of liquefiers, or even a small number of certain species of rapid liquefiers, the gelatin of the plate may be completely liquefied before the colonies have grown large enough to be differentiated. Under these conditions the experiment becomes a blank, and this difficulty of the liquefying bacteria very seriously interferes with the complete success of the method.

We have tried to meet the difficulty in several ways. We have tried to use agar instead of gelatin, but this is quite unsatisfactory inasmuch as the colonies are not differentiated on the agar as they are on the gelatin, and it is quite impossible to separate the species from each other on the former as they can be done on the latter. We have made a culture medium of agar and gelatin mixed; but while this makes possible a satisfactory differentiation, it does not so check the liquefaction as to be an improvement over pure gelatin. We have tried to put into each liquefying colony, as soon as it appears, a drop of a weak solution of formaldehyde to stop the growth of the bacteria, but this is futile, for the enzymes which have been produced continue to spread, and the liquefaction goes on as if the formaldehyde had not been added. Indeed, we have as yet been unable to meet this difficulty and as a result it happens occasionally, as will be seen on the following pages, that an experiment is quite blank because of the rapid growth of liquefiers, while in other cases the presence of liquefiers increases the number of colonies which are classed as undetermined.

DIFFERENTIATION OF SPECIES.

Milk to be studied is diluted by sterile water to an amount which previous experience has shown to be most likely to be useful. In the study of fresh milk as obtained from the milk

dealer, a dilution of one hundred to six hundred is commonly most satisfactory, but in warm weather this is too slight a dilution; and in the case of milk that has been obtained under uncleanly conditions a larger dilution is necessary. Milk which has been kept for one to two days in the laboratory requires, of course, higher dilutions; the oldest milk samples which we have studied required a dilution of 1–250,000 or even more. These high dilutions make it impossible to detect the presence of bacteria which are present in old milk in very small numbers only.

After dilution, a series of plates is made from each sample of milk and allowed to develop at ordinary room temperature for three or four days before an examination is made. The plates are then carefully studied for a differentiation of colonies. A partial differentiation is extremely simple and quite accurate. An examination of the plates after three or four days' growth enables one at a glance to differentiate the liquefying bacteria from the non-liquefying, and those which produce an acid reaction from those which produce an alkaline reaction or no reaction at all. It is also possible to differentiate the liquefiers readily into those which liquefy rapidly and those which liquefy slowly. A differentiation thus into four types, viz., into those producing an acid or an alkaline reaction and into rapid and slow liquefiers is extremely easy, very accurate, and can be made at a glance.

A further differentiation requires more careful study. We have, however, learned to separate about thirty species from each other by a study of their colonies in this litmus gelatin. For example, we have found that the most common organisms in milk which is a few hours old are three types of acid bacteria easily separated upon our litmus gelatin plates as follows:

1. *B. acidi lactici* (Esten) is, in this locality at least, the most common organism in milk. It produces a small, dense, intensely acid colony, growing only under the surface of the litmus gelatin, and showing after growing for about four days slight irregularities or spines on the edges. It is very easily distinguished.

2. *B. acidi lactici II.* (Conn) is also very common but not so abundant as the first. It produces an extremely minute transparent colony, hardly visible even with the lens, and quite invisible with the naked eye.

3. *B. lactici aerogenes* is also very frequently present, though rarely in numbers as great as those of the first two species mentioned. It produces a large, intensely acid colony, commonly growing on the surface, and forming frequently a thick, white bead, which occasionally develops a bubble of gas. Whether these colonies can be differentiated from those of *B. coli communis* we have not yet ascertained. The two organisms produce colonies very similar to each other, and while in some cases we believe that we can separate the two by the appearance of their colonies, we are not yet sure of this differentiation. In our tables, therefore, the column which is headed "*B. aerogenes*" includes *B. aerogenes* and *B. coli communis*, if the latter is present, no attempt being made in these tables to differentiate the two.

4. Next to the acid bacteria the most common organism is a type which produces no change in the action of the litmus, but develops a small, opaque colony quite easily recognized. It produces a slightly alkaline reaction which sometimes neutralizes the acid of neighboring lactic colonies. This organism, which in the tables is called a streptococcus, is found in nearly every sample of milk, and evidence given elsewhere has indicated that it is present in the udder of the cow, so that the milk ducts may be regarded as at least one of its sources. It does not represent a single species of bacteria but rather a group of allied forms. We have found that among the organisms tabulated under this name their are several species, all agreeing in producing no noticeable action on the litmus gelatin or in milk. Some are streptococci and others are short bacilli. Since the different species cannot be readily differentiated upon our plates we group them of necessity under one head, designated the *streptococcus* group.

5. We have divided the liquefying bacteria into two groups. The first, called *rapid liquefiers*, liquefy the gelatin very rapidly; while the second, called *slow liquefiers*, require several days to produce liquefaction, and even on the older plates the colonies are small, never extending over the plate. A further differentiation is doubtless possible but it has not as yet been attemped.

6. *Sarcina lutea* proves to be almost uniformly present in our milk. It is easily distinguished from other colonies by its yellow color, which reddens the litmus around it. All *yellow acid* colonies have proved to be this species.

In addition to these common forms there are some twenty or more other species of bacteria which are found very frequently in milk in this vicinity. Most of these types are easily separated from each other by the study of their colonies in gelatin. Some of them produce pigments, some of them produce colonies of peculiar shapes, and in regard to others there are characters which enable us to recognize the species by the study of the colony. These different species are included in the following tables in appropriate columns, and on later pages will be given further descriptions as to the method by which the more important colonies are distinguished in gelatin.

We recognize that the differentiation thus obtained is never exact and that there is always a considerable possibility of error. It is not possible with certainty to separate *B. aerogenes* and *B. coli;* it is quite certain that the *Streptococcus* group consists of more than one kind of bacteria, and the liquefiers are certainly several species. It is probable in regard to the other types also that errors occur and that sometimes different species of bacteria produce colonies so much alike that they are not differentiated in our tables. Moreover, in cases where liquefiers are abundant it is sometimes necessary to study the plates before the colonies are grown sufficiently for proper differentiation. At best, therefore, the differentiation which is given in the tables must be recognized as only approximate. We are convinced, however, that the error is not very great and that the numbers which are given in the tables herewith may be taken as expressing an approximation to the actual number of the species present in the milk. At all events, while recognizing the possible errors of this method it seems to us that the results obtained are considerably in advance of those hitherto obtained in the study of bacteria in milk. They give much new information and are therefore likely to be useful in the solution of various problems even though not strictly accurate.

CALCULATION OF RESULTS.

A little explanation is necessary as to the method of calculating results. The plates have been allowed to grow three or four days, and then studied as follows: The total number of colonies is counted. The number of colonies of each clearly

distinguishable type is carefully counted by the use of a lens, provided the total number of colonies on the plate is not too great. Where the number of colonies on the plate is only three to four hundred it is quite easy to calculate the number of each type accurately. It is usually found that when the numbers of all of the different species distinguished are added together they do not produce a total equal to the whole number of bacteria that may be found by counting all the colonies. There have been left, in most experiments, a certain number of colonies which have not been recognized as belonging to any of the differentiated types; these have been included in the tables in the column headed "undetermined." The bacteria included in this column are probably in most cases the same species as those that are classified under the other columns, but colonies which have not developed sufficiently for a sharp differentiation. In plates which it has been necessary to study when only two days old the number present in the column of undetermined is greater than it is in the older plates, for this reason.

Where study is made of milk that is somewhat older and the number of bacteria consequently considerably larger, the method of calculating results is slightly different, due to the vast preponderance of one species, *B. acidi lactici.* The dilutions which have been used in old milk and cream have been very much greater than those in the fresh milk (sometimes 250,000); nevertheless the number of colonies on each plate is always greater. In the study of these plates we have first calculated the total number of colonies that can be counted. Then each plate is carefully studied with a lens and a microscope, and every colony on a plate which is different from the *B. acidi lactici* colony is counted and tabulated. A careful study thus enables us to determine, with close accuracy, every colony that does not belong to the typical No. 206. It has then been assumed that the rest of the colonies belong to this species, and their number determined by calculation. The number thus determined is quite probably somewhat too high in every case, since it is almost certain that some of the colonies of the miscellaneous bacteria escape observation and would be included in the column of No. 206. We are convinced, however, that this error is not very great, inasmuch as

this particular organism is very readily differentiated and the chance of error is thus greatly reduced. It is only in the older samples of milk that this method has been adopted, and was not used in any of the tables given below except Tables 1 and 2, since the milk was fresh and the differentiation of each type of colony could be made directly.

The topics which have been studied at the Station by the method here outlined during the last year have divided themselves into several distinct problems. Some of them have been worked out in the laboratory at Wesleyan University, and others in the newly equipped bacteriological laboratory at Storrs.

1. THE COMPARATIVE GROWTH OF DIFFERENT SPECIES OF BACTERIA IN MILK KEPT AT A TEMPERATURE OF 20 DEGREES CENTIGRADE.

The first series of experiments to be described were carried on with milk preserved at ordinary room temperatures. In order to determine the effect of different conditions upon the growth of bacteria in milk, it is necessary to have a knowledge of their normal growth under ordinary conditions. For this purpose it was thought best to study with considerable detail a number of samples of milk preserved at an ordinary room temperature, and this series of experiments will be described first, although not actually the first to be carried out.

It will be seen by the tables that follow that the study of this milk did not extend beyond the first twenty-four hours. The reason for this is as follows: So far as concerns the bacteriological study of normal market milk the first twenty-four hours are of special significance. It is true that sometimes milk of our cities is considerably older than this by the time it is distributed to the customers, but when that is the case the milk has been kept at a low temperature, which as will be seen later modifies the problem. The milk which is furnished the customers of our cities is never supposed to be sour, or even upon the verge of souring; but our own experience has shown that after twenty-four hours at a temperature of 20° C., the milk begins to become strongly acid and before many hours is likely to curdle. It has appeared to us therefore, that the study of the growth of bacteria during the first twenty-four hours,

while the bacteria were fewer than 10,000,000 per cubic centimeter, was of more significance than the study of the same problem in later hours. Moreover, in a previously published work* we have shown that, in cream, in the later hours the development of the bacteria is always of the same general character. It has been there shown that the development of the bacteria in the period of ripening always results in the disappearance of most of the miscellaneous bacteria and the excessive multiplication of two or three species of lactic bacteria. In some of the experiments reported later in the present article it will be seen that these same facts were demonstrated to be true of milk which had been kept more than twenty-four hours. The first twenty-four hours, therefore, are those in which the numerous species of bacteria in milk may be expected to develop or decline. These considerations together have convinced us that the most useful foundation for a study of the growth of different species of bacteria in milk is the careful analysis of the development of bacteria during the first twenty-four hours. In this series of experiments, therefore, the analyses extended over a period of only about twenty-hours, the tests being made at intervals of about six hours, with slight variations to suit convenience.

The results obtained in the experiments are given in the tables on the following pages. There are two tables for each experiment, which may be explained as follows:

In the first table the first column gives the number of hours after milking at which the different sets of plates were made. The second column gives in round numbers the total number of bacteria per cubic centimeter in the milk at the different periods. Each succeeding column gives the number of a particular species or group of bacteria capable of differentiation upon the litmus gelatin plates. A dash inserted in the column indicates that none of the colonies of that species were discovered on the plates; an interrogation point signifies that the number of bacteria was so small as not to be included in the count, although not entirely absent from the sample of milk.

In any period the sum of the numbers given in the different columns should in reality be equal to the total number given in the second column; as a matter of fact, however, discrepancies

* Storrs Expt. Sta. Rept., 1900.

are common, for the reason that in all the columns the numbers are not exact but only approximate and, except when very small, are given to the nearest tens, hundreds, or thousands, as the case may be.

In the second table the figures in the different columns show what proportion the numbers of bacteria of the various species formed of the total number of bacteria present. These percentages are calculated not from the approximate numbers given in the first table, but from the numbers actually found. They therefore vary slightly, in some of the columns, from the percentages that would be calculated from the first table because of the fact explained above that the figures in the first table are given only in round numbers.

It appeared to us that the figures in the second table are fully as significant as those in the first, since the percentages alone show the development of the different bacteria as compared with each other. If, for example, a given species of micro-organism should remain in the milk during the whole period of experimenting, with only a slight increase in numbers, the first table would always show an increase during the period of experiment; the second table would, however, show a constant decline, meaning of course that the percentage of the species in question was becoming constantly less as the other bacteria were increasing during the experiment. On the other hand, a species that showed a constantly increasing percentage would be one which would of necessity have an important influence upon the milk.

In the tables which are here given the bacteria tabulated in the first eight columns are those which we have found present with a very considerable degree of constancy in all samples of milk. The species in question may be briefly mentioned as follows:

B. acidi lactici. This is the species described by Esten in a previous report.* It has been found by many bacteriologists and is widely distributed in this country. It is apparently identical with *B. acidi paralactici* described by Kozai† as the most common lactic organism in Europe. It is the species which we find with the greatest uniformity in milk, and the

* Storrs Expt. Sta. Rept. 1896, p. 44.
† Ztschr. f. Hyg. XXXVIII. 386, 1901.

one which is present frequently to the extent of more than 90 per cent. in ripened cream. The source of this organism has been shown by Burr* to be commonly outside of the cow, and probably the dirt and dust in the air of the stable. It is present, as may be seen in all the following tables, in small numbers in fresh milk, and then with almost absolute uniformity it increases in numbers and percentage until the end of the experiments.

B. acidi lactici II. This is a species which we have found quite common in this region, though less common than the previous. In many respects it resembles the preceding organism and may possibly be a variety of the same. We have found that in most cases it is not observable in the samples of fresh milk but makes its appearance in the later stages of souring.

B. lactis aerogenes. As indicated above, the organisms included under this title in the tables may be not only *B. aerogenes* but also *B. coli*, should it chance to be present, inasmuch as these species are not readily differentiated upon the gelatin plates. We are convinced by the study of large numbers of colonies, however, that in the vast majority of cases the organisms tabulated here are *B. aerogenes*, and only a comparatively small proportion consist of *B. coli.*

The *Streptococcus* we have found with absolute uniformity in all samples of milk which we have studied. It is usually very abundant, though sometimes in small numbers only. It apparently comes in many cases from the udder of the cow. Its colony on the litmus gelatin has already been described.

Sarcina lutea is found almost universally in samples which we have studied. We have also found a *Sarcina* which in the early stages appears to be different from it, but later develops into a somewhat similar colony; this we have tabulated as *Sarcina II.*, regarding it as a different species from the first.

The column headed *rapid liquefiers* is made up of probably two and possibly three species. These are bacteria which grow with extraordinary rapidity, and occasionally may completely liquefy a gelatin plate in the course of twenty-four hours and

* Storrs Expt. Sta. Rept. 1900, p. 66.

utterly ruin the experiment. Fortunately, they are not very abundant, and while they have frequently rendered the examination impossible, they have not seriously interfered with the value of the experiments. There are, as stated, possibly three species which differ somewhat in the rapidity of their growth.

The column headed *slow liquefiers* consists of a large number of species which we have as yet made no attempt to differentiate in these experiments. They can be quite readily differentiated on the gelatin plates because the colonies are very different from each other, but in our previous work we have not made any attempt to do it.

The bacteria tabulated in the other columns in the tables are species which are present in smaller numbers and with greater irregularity. These organisms may perhaps be regarded as normal to milk, but they are by no means constant and each sample of milk differs from the other chiefly in the variety and the number of these miscellaneous types of bacteria. Some of them are more commonly found than others, but none of them appear with much constancy and, as will be seen by the examination of the following tables, rarely do they develop in the milk in such a way as to suggest that they are of any considerable importance. Some of them appear to be quite incapable of adapting themselves to the conditions and fail to grow; others multiply slowly, but even to the end of the experiments are only present in small numbers; they are, therefore, of far less significance in the milk than the bacteria in the first eight columns.

No attempt will be made at this place to describe the species which are thus tabulated. Some of them have already been described in the "Classification of Dairy Bacteria," given in a previous publication of the Station;* others are being now, or have been, worked out in our laboratory, and will be described in a revised edition of this classification which will be published at some future time. For the purpose of the experiments here given it is quite unnecessary to describe the character of the different species; they may be referred to simply by number or by letter, with the understanding that in other publications the characters of the species are or will be given in detail.

* Storrs Expt. Sta. Rept., 1899, pp. 13-68.

TABLE 1.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 20° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Rapid liquefiers.	Slow liquefiers.	No. 217.	No. 219.	No. 220.	Undetermined.
0, - - -	25000	3300	—	?	9400	1200	950	50	8350	400	850	400	800
6, - - -	25000	2500	—	?	6800	2200	1200	?	10000	80	?	420	1800
14, - - -	162000	24000	—	?	47000	15000	8000	?	50000	3900	1200	10000	2900
18, - - -	295000	60000	—	26000	68000	16000	6000	5000	67000	3000	?	?	43000
24, - - -	6246000	3814000	—	367000	1086000	233000	163000	53000	470000	?	?	?	83000

TABLE 2.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%	%	%	%	%
0, - - -	—	12.6	—	—	36.3	4.6	3.6	.2	32.9	1.7	3.4	1.7	3.0
6, - - -	—	9.9	—	—	26.5	8.9	4.8	—	42.4	.3	—	1.3	5.9
14, - - -	—	14.8	—	—	29.9	9.1	4.9	—	30.8	2.5	.7	6.0	1.3
18, - - -	—	18.0	—	14.4	22.7	6.5	1.7	1.4	21.8	.9	—	—	12.6
24, - - -	—	61.0	—	6.0	16.5	3.9	2.9	.9	7.5	—	—	—	1.3

Experiment No. 1. November.—The milk in this and all other experiments of this section was taken from a single cow at the barn of the Connecticut Industrial School for Girls in the vicinity of Middletown. It was taken at once to the laboratory and the first set of plates made from it while the milk was still warm; it was then kept at 20° C. and other plates were made at intervals of about six hours until the milk was twenty-four hours old. The results are shown in Tables 1 and 2 on page 30.

The study of the figures given in these tables shows the following salient facts:

1. During the first six hours there was no change in the number of bacteria in the milk and practically no change in the varieties found. The slight differences in numbers and percentages given in the table are possibly only errors in the method, although they may indicate an actual change in the relative number of the different species of bacteria.

2. From the beginning of the experiment to the close there was a constant increase in the number of *B. acidi lactici*. This was an increase not only in actual numbers, but also in percentage, the milk at twenty-four hours old showing 61 per cent. of this species.

3. *B. acidi lactici II.* was not found on the plates.

4. *B. aerogenes* played no considerable part in this experiment. It was not found in the earlier tests and appeared only in the last two.

5. The *Streptococcus* shown in the fourth column existed in very great numbers at first and continued to increase in numbers through the series of tests. The percentage, however, as shown by Table 2, underwent a tolerably constant decline, and was at the close only half as great as at the beginning.

6. The two species of *Sarcina* were present in moderate numbers throughout the whole series; they increased slowly in actual numbers but there was a decline in relative abundance.

7. The number of *liquefiers* was excessively high, there being at the outset about 30 per cent. of the bacteria that liquefy gelatin. This number remained quite high throughout the whole series. There was noticed an increase in percentage at the end of six hours, but that was followed by a somewhat rapid decline and at twenty-four hours the proportion had dropped to 7.5 per cent. There was an increase in total numbers, however, up to the very last test.

8. The miscellaneous bacteria, of which three species are recorded, were not abundant, the numbers being only a few hundred and the proportions less than 4 per cent. It will be seen, moreover, that while there was slight increase in actual numbers of these bacteria for a few hours, there was a constant decline in percentage, and in the tests that were made at twenty-four hours these species did not appear at all. This does not necessarily indicate that they were totally absent, because the dilutions that were necessary at twenty-four hours were so much greater than those required at the end of six hours that a small number of these miscellaneous species would be very likely to escape observation in the plates. While, therefore, their absence from the tables in the figures for the later tests indicates that they had not increased in number appreciably during the experiment, it does not indicate that they were totally absent from the milk.

9. The number of colonies that were undetermined in these tests is shown by the last column to be somewhat variable, in one test rising to 12 per cent., but in the other cases being about 3 per cent. or less.

Experiment No. 2. November.—This experiment was a repetition of the last and occurred five days subsequently. The conditions of the experiment were identical with those of Experiment No. 1. The results of the tests made up to the age of twenty-four hours are shown in the two following tables.

Table 3.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 20° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Rapid liquefiers.	Slow liquefiers.	No. 217.	No. 219.	No. 220.	a	b	c	d	Undetermined.
0, -	13000	400	—	?	3150	200	2350	45	4200	290	1600	190	?	?	?	?	840
6, -	13000	420	—	75	2700	75	1350	140	3600	190	1950	50	400	50	50	25	1400
14, -	12700	520	—	240	3400	?	350	240	5900	150	1150	?	100	—	—	100	620
19, -	41800	5300	—	5000	4400	625	?	650	20000	?	2200	1250	—	—	—	—	2825
24, -	716000	158000	—	100000	205000	15000	?	14000	64000	?	76000	?	—	—	—	—	43000

Table 4.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
0, -	—	3.2	—	—	24.0	1.6	17.9	.4	31.6	2.2	11.8	1.3	—	—	—	—	6.0
6, -	—	3.6	—	.6	21.7	.6	10.5	1.1	28.9	1.4	16.1	.4	3.1	.4	.4	.2	11.0
14, -	—	4.5	—	1.6	26.1	—	2.5	1.6	48.0	1.7	8.6	—	.7	—	—	.6	4.1
19, -	—	13.0	—	11.3	10.9	1.4	—	1.7	50.0	—	5.2	2.6	—	—	—	—	5.9
24, -	—	25.1	—	16.3	27.7	2.3	—	1.5	9.9	—	10.3	—	—	—	—	—	6.9

An examination of the tables of this experiment given on the preceding page shows the following facts:

1. During the first six hours there was no appreciable change in either number or variety of bacteria.

2. The numbers of *B. acidi lactici* showed a constant increase in the successive tests. The number, however, did not become so high as in the first experiment, and the percentage at the end of twenty-four hours was only 25, the actual number being also very small.

3. The presence of *B. acidi lactici II.* was not observed in any of the tests.

4. *B. aerogenes* was abundant in this sample of milk. It was not observed in the plate made from fresh milk, but a few colonies were found in the milk at the age of six hours. From that point they continued to increase until the end, when they reached the number of 100,000 and a percentage of 16.3. This, it should be remarked here, is a very high percentage for this species of bacterium, as may be seen by comparing Table 4 with the other tables on the following pages.

5. The *Streptococcus* was quite abundant throughout the whole series of tests, but while increasing constantly in numbers showed no appreciable change in percentage. The test made at nineteen hours indicated a dropping off in the number of the *Streptococcus* colonies, probably due to an imperfect differentiation between this species and *B. acidi lactici*, which sometimes resemble each other.

6. The two species of *Sarcina* were present in all tests and slowly increased in numbers. One species remained throughout with a practically constant percentage, while the other species fell off from a high proportion of about 17.9 per cent. down to about 2.5 and then disappeared.

7. In this sample *liquefiers* were also very abundant. They increased with unusual rapidity during the first nineteen hours; afterwards they declined with equal rapidity, and in the last test only about 10 per cent. were found. There was, however, a constant increase in total number of liquefiers.

8. The milk showed an exceptionally large number of miscellaneous bacteria, as will be seen from Table 3. It will also be noticed that these miscellaneous types must play a very small part in the changes that occur in milk. They were present only in small numbers at the start and in milk that was six hours old, and then disappeared, only one species increasing in numbers up to the close of the experiment. The rest were indistinguishable on the last series of plates.

9. The number of undetermined bacteria in these plates was somewhat variable but not very large. It should be noticed, however, that the large number of liquefiers which were present at fourteen and nineteen hours made a sharp differentiation of *B. acidi lactici* and the common *Streptococcus* difficult, and probably explains the slight irregularities shown in the two tests.

10. It is to be noticed finally that the total number of bacteria at the end of the experiment was very small. This is shown by a comparison of the numbers given in Table 3 with those in Table 7; it will be seen that whereas in the later experiment the number at the start was 8,000 and increased in twenty-seven hours to 3,000,000, in the present experiment, as shown by Table 3, the number at the start was 13,000 but at the end of twenty-four hours only 716,000. This is simply one instance of what we have found to be a general rule, that the number of bacteria at the start gives very little indication of the number that there may be present after twenty-four hours even under similar conditions.

TABLE 5.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 20° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Rapid liquefiers.	Slow liquefiers.	No. 217.	No. 219.	No. 221.	e	Undetermined.
0, -	19000	1200	—	—	4800	1400	2600	20	2900	300	1200	800	—	3650
6, -	15000	1400	—	—	3250	2250	2000	?	2550	400	575	1000	?	1450
13, -	63000	23200	1250	—	6450	5800	2500	225	9425	?	400	—	400	13000
20, -	713000	309000	29000	—	9450	130000	15000	10500	38000	?	—	—	?	88000
29, -	11000000	5500000	263000	—	2400000	340000	405000	178000	688000	?	—	—	125000	900000

TABLE 6.

Percentages of bacteria of different species included in the total numbers above.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Rapid liquefiers.	Slow liquefiers.	No. 217.	No. 219.	No. 221.	e	Undetermined.
		%	%	%	%	%	%	%	%	%	%	%	%	%
0, -	—	6.4	—	—	25.1	7.1	13.6	.1	15.0	1.6	6.3	5.5	—	19.3
6, -	—	9.1	—	—	24.2	15.4	13.0	?	16.7	2.7	3.5	6.4	—	9.0
13, -	—	37.0	1.9	—	10.4	9.3	4.0	.4	14.9	—	.8	—	.6	20.7
20, -	—	43.1	4.1	—	13.3	18.1	2.1	1.5	5.3	—	—	—	—	12.5
29, -	—	53.5	1.8	—	21.1	3.0	3.8	1.6	6.5	—	—	—	.8	7.9

Experiment No. 3. December.—This experiment is a repetition of the last two and was performed under identical conditions. The results are shown in Tables 5 and 6 on page 36.

The general conclusions from these tables are as follows:

1. There was a constant increase in numbers of *B. acidi lactici* and a tolerably constant increase in percentage. The percentage in the last test reached 53.5.

2. This sample of milk showed the presence of the species called *B. acidi lactici II.*, which were found, however, in the last three tests only.

3. *B. aerogenes* was not found.

4. The *Streptococcus* group was present in large numbers and continued to increase in number constantly throughout the experiment, reaching at the end the number of two million and a half. The percentage of colonies of this species also remained high and, with some fluctuation in two tests due doubtless to the high per cent. of undetermined colonies, was at the close nearly as high as at the beginning.

5. The two species of *Sarcina* increased constantly in numbers during the whole experiment, but decreased in percentage; in the last test the relative abundance was less than one-third of that in the first test.

6. *Liquefiers* did not occur in so great numbers as in the other experiments. While there was moderate increase in total numbers, there was a decrease in percentage, and at the end they formed a much smaller proportion of the total numbers than at the beginning.

7. There were about four miscellaneous types of bacteria which, as in the other cases, were present in small numbers in the first one or two plates and disappeared so as not to be detected in the later tests.

8. The total number of miscellaneous species was somewhat larger in this experiment than in the other two.

TABLE 7.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 20° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Rapid liquefiers.	Slow liquefiers.	No. 217.	No. 219.	a	f	Undetermined.
0, - - - -	20000	775	—	—	4200	1200	950	150	5150	250	400	200	—	7000
6, - - - -	18600	1300	—	—	6100	900	1900	58	00	250	700	300	50	1350
13, - - - -	65000	1950	—	—	8750	9500	6300	600	34000	—	1250	—	—	3000
18, - - - -	98000	16500	—	—	15000	8000	4600	?	46000	—	—	—	—	7700
24, - - - -	4133000	215000	—	—	2796000	82500	58000	59000	896000	—	—	12500	—	50000

TABLE 8.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%	%	%	%	%	%
0, - - - -	—	4.0	—	—	20.5	5.8	4.5	.8	25.2	1.2	2.0	1.0	—	35.0
6, - - - -	—	7.1	—	—	33.0	5.1	9.8	31	.0	1.3	3.6	1.8	.3	7.0
13, - - - -	—	2.7	—	—	14.0	15.8	10.0	.9	50.4	—	1.4	—	—	4.8
18, - - - -	—	16.9	—	—	15.3	8.2	4.7	—	47.0	—	—	—	—	7.9
24, - - - -	—	7.5	—	—	48.0	5.1	3.0	3.6	29.7	—	—	1.4	—	1.7

Experiment No. 4. November. This experiment was performed under conditions identical with those of the other three. The results are shown in Tables 7 and 8.

The significant facts shown by this experiment are as follows:

1. The usual increase in total number of bacteria and in total number of each of the common species of micro-organism is seen. As in the other cases the few species of miscellaneous bacteria, present at the outset in small numbers, failed to increase and disappeared in the later tests of the experiment.

2. A study of the table of percentages shows certain irregularities from those of the other experiments. There fails to be a regular increase in the proportion of *B. acidi lactici*. The *Streptococcus* group also shows irregularities. The third and fourth tests indicate a smaller number of this group than the second and fifth. The explanation of this is beyond doubt given in the column of liquefiers, for it will be seen that the proportion of these organisms in this milk was excessively high, in the third and fourth test reaching 50 and 47 per cent. This high percentage of liquefiers made it impossible to keep these particular plates until the *B. acidi lactici* and the *Streptococcus* groups were properly differentiated, and the estimates of these two species upon the third and fourth plates are, therefore, quite unreliable. The same statement must be made in regard to the two species of *Sarcina*, which in young plates are not easily differentiated from *B. acidi lactici* or the *Streptococcus* group. As a consequence the numbers given of these three species in these two tests are not satisfactory.

TABLE 9.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 20° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Rapid liquefiers.	Slow liquefiers.	No. 219.	No. 220.	No. 217.	Undetermined.
0, - - - - -	8000	501	—	—	2100	950	1300	—	1900	350	900	35	—
6, - - - - -	7300	300	—	—	1400	1200	1300	—	2100	300	700	—	—
14, - - - - -	20000	6100	—	—	2900	1500	150	—	8850	600	—	—	—
20, - - - - -	195000	12800	—	—	29900	11450	23300	—	118000	2250	—	—	—
27, - - - - -	3500000	253000	—	31250	149100	375000	?	31000	1219000	?	—	—	391000

TABLE 10.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%	%	%	%	%
0, - - - - -	—	6.3	—	—	25.8	12.0	17.2	—	23.5	4.0	10.8	.4	—
6, - - - - -	—	3.9	—	—	19.6	17.0	17.7	—	27.3	4.1	10.4	—	—
14, - - - - -	—	30.9	—	—	13.4	7.5	.5	—	44.9	2.8	—	—	—
20, - - - - -	—	6.7	—	—	15.5	5.8	10.0	—	60.9	1.1	—	—	—
27, - - - - -	—	13.2	—	2.2	28.2	1.8	—	.3	50.3	—	—	—	4.0

Experiment No. 5. December. The milk in this experiment was obtained from a different cow from that of the other experiments, but from the same stable. In other respects the conditions were identical. The results are shown in Tables 9 and 10.

From these tables the following facts may be noticed:

1. There is a constant increase in the numbers of *B. acidi lactici*, both in total numbers and in percentage. They did not, however, reach a very high percentage in any of the experiments. It will be noticed that the 30.9 per cent. given in the fourteen hour test was anomalous. This is doubtless an error introduced by the liquefiers, as mentioned below.

2. The other two common acid bacteria did not appear in this sample of milk, with the exception of a small number of *B. aerogenes* found in the last plate.

3. The *Streptococcus* group was abundant and increased in total numbers regularly through the whole series of experiments, though the percentage remained practically constant.

4. The total number of the two *Sarcina* species underwent a constant increase, but there was a decrease in percentage, so that in the last tests they had become a very small fraction of the whole, less than 2 per cent.

5. The most peculiar feature of this sample of milk was the excessive number of liquefiers, which was greater than in any other test we have made. Moreover, they continued to increase until almost the very end, rising in proportion from 23.5 to 60.9 per cent. at the end of twenty hours, and then falling to 50 per cent. at the end of twenty-four hours. This large number of liquefiers made the differentiation of the acid organisms and the *Streptococcus* group difficult and unsatisfactory, and it is quite probable that the numbers given in the second and fourth columns are in this case not reliable.

6. There were only two species of miscellaneous bacteria present in this sample. They were few in number and they disappeared totally from the plates in the later tests.

TABLE 11.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 20° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Rapid liquefiers.	Slow liquefiers.	No. 219.	No. 220.	a	Undetermined.
0, - - - - -	19500	—	—	—	5400	550	350	?	1950	240	3280	—	7725
6, - - - - -	19000	—	—	—	5000	500	225	?	2250	150	4500	—	6500
14; - - - - -	82000	2300	—	250	3350	1150	300	250	47500	1650	7050	250	18000
20, - - - - -	561700	27000	—	—	57000	?	14000	6000	368000	1700	5000	—	83000
27, - - - - -	2060000	336000	—	—	634000	84000	24000	52500	852000	6000	?	—	75000

TABLE 12.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%	%	%	%	%
0, - - - - -	—	—	—	—	27.9	2.8	1.9	—	10.1	1.3	17.3	—	38.7
6, - - - - -	—	—	—	—	26.6	2.7	1.3	—	11.7	1.0	24.4	—	32.3
14, - - - - -	—	2.8	—	.3	4.1	1.4	.4	.3	57.9	2.0	8.8	.3	21.7
20, - - - - -	—	4.9	—	—	10.2	—	2.6	1.1	65.5	.3	.9	—	14.5
27, - - - - -	—	16.6	—	—	31.2	3.9	1.1	3.1	39.4	.3	—	—	4.4

TABLE 13.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 20° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Rapid liquefiers.	Slow liquefiers.	No. 219.	No. 220.	f	Undetermined.
0,	32000	6000	—	—	4650	1850	1375	100	1700	3000	7700	2550	3300
6,	23600	3700	—	—	3600	1600	1300	100	1900	1000	6100	2250	2000
14,	153000	112000	1600	—	4800	1050	1050	—	21200	1950	2600	4400	1700
20,	Dilution was made too small because the number was unexpectedly large.												
27,	43500000	35000000	7000000	—	174000	?	—	—	278000	—	?	—	1000000

TABLE 14.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%	%	%	%	%
0,	—	18.2	—	—	14.0	5.8	4.3	.4	5.3	9.4	23.7	7.8	11.1
6,	—	15.6	—	—	15.6	6.6	5.0	.3	8.3	4.7	25.2	9.6	9.1
14,	—	72.6	1.0	—	3.3	.7	.7	—	14.4	1.3	1.8	3.0	1.2
20,	—	—	—	—	—	—	—	—	—	—	—	—	—
27,	—	78.9	16.5	—	.4	—	—	—	.6	—	—	—	3.6

Experiments Nos. 6 and 7. January. — The two present experiments were performed in the month of January at a time when the cows were kept in the barn and, therefore, under conditions quite different from those of the previous experiments. These two experiments are especially striking as showing the extraordinary variation in results which are obtained under conditions that are apparently identical. The two experiments were performed within two days of each other, one upon January 15, and the other upon January 17. In both cases the milk was obtained from the same cow, at the same stable, and the samples were treated in identically the same manner. The results, however, were for quite inexplicable reasons very unlike. The four tables on pages 42 and 43 give the results of these two experiments.

In considering the results given in the above tables we notice first the great differences between those for the two samples which were, so far as we could determine, obtained and kept under identical conditions. The differences will be seen in the following points:

In the first sample the number of bacteria rose in twenty-six hours to 2,000,000; in the second sample they increased in twenty-seven hours to 43,000,000. This difference seems to be totally unexplained by the conditions of the experiment.

A second point of difference was the number of the common *B. acidi lactici*. In the first experiment they were not found in the fresh milk or milk six hours old, although it is probable that some of the undetermined bacteria were of this species. The number arose only to 16 per cent. at the last test, at twenty-six hours. In the second experiment the number of this species at the outset was 18 per cent. and it constantly increased until at the last test it was nearly 80 per cent. These differences are partly explained by the large percentage of undetermined species in the first experiment, but even if all of the undetermined bacteria were placed in the column of acid organisms it would still leave a surprising difference between these two samples of milk as regards the development of this particular species.

A third great difference is in the number of the *Streptococcus* group which in the first experiment was very high and in the last experiment, especially in the later tests, exceptionally low,

falling at the end to .4 of one per cent. The actual numbers were, however, large in the last experiment, showing that the small percentage of these organisms was due to the large numbers of *B. acidi lactici*.

A fourth point of difference was in the liquefiers. Whereas in the first experiment the number of liquefiers was 10 per cent. at the outset and rose to 65 per cent., falling at the end to 39 per cent., the number in the second experiment was in no case over 14 per cent. and at the end had fallen to .6 of one per cent.

There are other minor differences that may be made out from the study of the tables but these four represent the more important. It is not improbable that it was the great development of liquefiers which modified the development of the other species and that the difference between these two samples is to be explained by the fact that for some quite inexplicable reason the liquefiers developed rapidly in the first sample and failed to develop in the second sample.

When these two tables are compared with those of experiments of earlier dates, Tables 1–10, there are found to be no very considerable differences. There is in each case an increase of acid organisms, a decrease in the miscellaneous species and a general increase in liquefiers. It will be noticed, however, that the experiment of January 17 was in some respects quite anomalous. The number of acid bacteria at the end of twenty-seven hours is much greater than in any previous experiment described. The total number of bacteria is very large, 43,000,000, and of these over 90 per cent. are lactic bacteria. The result of this is, as seen by Tables 12 and 14, that most of the other types of micro-organisms have become reduced in proportion or have quite disappeared. The results obtained in this experiment are quite similar to those which have been given in a previous report* upon the development of bacteria in the late stages of cream ripening, where, as has been shown, the excessive development of lactic bacteria forces all other species to the background and eventually appears to destroy them. This sample of milk at the age of twenty-seven hours is, so far as concerns its type of bacteria, quite similar to the samples of milk and cream of a very much older age which are described elsewhere.†

* Storrs Expt. Sta. Rept., 1900, pp. 13–33.

† Loc. Cit.

It is possible that the experiment of January 15 should be excluded from our series, the excessive number of liquefiers interfering so materially with the proper differentiation of species that the column of undetermined is an extremely large one. At all events, too much value must not be placed upon this experiment, but we have included these tables for the purpose of showing, if nothing else, the variations and the difficulties of determining the strict differentiation of species under these conditions.

Further tables giving the growth of bacteria at 20° C. will be found in the later sections of this paper, but since they do not materially change the facts already given it will be well to summarize at this point the results obtained.

GENERAL SUMMARY.

If we compare the foregoing experiments we shall notice the following facts:

1. There are considerable irregularities as to both total numbers and increase of different species under what seem to be identical conditions. There is in all cases a constant increase in the total numbers of bacteria of each of the species given in the first eight columns of our tables. The miscellaneous species are always present in small numbers, but they disappear in the later tests in all cases, which means that they have not increased materially during the experiment.

2. There is in all experiments a constant increase in the percentage of *B. acidi lactici.* This indeed is the only one of the bacteria found in milk in these samples which shows a constant increase in percentage during the successive tests.

3. The *Streptococcus* group is present in all cases in considerable abundance, continues to multiply during the first twenty-four hours, and commonly just about holds its own in percentage. This indicates that, as a rule, it multiplies more rapidly than any of the other species except *B. acidi lactici.*

4. The two species of *Sarcina* are universally present in the milk and continue to increase in numbers in all experiments, but their percentage generally declines somewhat, so that they are relatively less abundant in twenty-four hours than at the start.

5. The liquefying bacteria show the greatest fluctuation. In all plates they increase in actual numbers and in some experiments they have increased in relative abundance for twenty hours. In others there is, however, a decline of percentage and there is thus a general indication that they do not multiply so rapidly as the *B. acidi lactici* and the *Streptococcus* group, although their increase is quite appreciable in all of these experiments.

6. The miscellaneous bacteria may be two or three species or half a dozen, or even more; but they are present in small numbers. They do not greatly multiply during the first twenty-four hours, and at the close either have disappeared or are present in such small numbers as not to be noticeable in the tests. They cannot, therefore, be of much significance in the changes that occur in the milk.

7. In general it will be seen that in these experiments the bacteria which are chiefly concerned in producing the changes which must take place in the milk are the *B. acidi lactici*, the *Streptococcus* group, and the liquefiers. The slow liquefiers in all cases were not only much more abundant than the rapid liquefiers but they multiplied more rapidly in the milk.

II. THE EFFECT OF ICING THE MILK UPON THE DEVELOPMENT OF BACTERIA.

The experiments described below were part of a series designed to determine the effect of the preliminary icing of the milk upon the growth of bacteria. Several experiments were performed, but only these two are given here, since these are the only ones in which the results were satisfactory. The method of experimentation was as follows:

Experiment No. 8. October. The milk was drawn directly from the cow into sterilized vessels, taken immediately to the laboratory, and a number of plates were made from it at once. The rest of the milk was then divided into two lots, one of which was placed upon ice for fourteen hours, and the other was kept for the same time at the normal room temperature of 20° C. without the preliminary icing. At the end of fourteen hours some plates were made from both lots of milk, and from that time plates were made every twelve hours from both samples until the milk was curdled.

TABLE 15.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 20° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Liquefiers.	Undetermined.
0, - - - - - -	115000	28240	440	40	15300	5490	17380	1680	47000
14, - - - - - -	Not sufficiently diluted and hence not trustworthy.								
26, - - - - - -	124000000	40000000	6500000	1000000	53000000	—	—	950000	23000000
38, - - - - - -	541000000	370000000	122000000	3000000	45000000	—	—	600000	—
50, - - - - - -	1050000000	750000000	290000000	4000000	6800000	—	—	500000	—

TABLE 16.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%
0, - - - - - -	—	25.9	.3	.1	12.8	1.4	16.4	1.4	41.7
14, - - - - - -	—	—	—	—	—	—	—	—	—
26, - - - - - -	—	31.2	5.4	.8	42.9	—	—	.7	19.0
38, - - - - - -	—	68.4	22.6	.6	8.3	—	—	.1	—
50, - - - - - -	—	71.6	27.4	.4	.6	—	—	—	—

TABLE 17.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk iced for fourteen hours and then kept for different periods at 20° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Liquefiers.	No. 85.	Undetermined.
0, - - - - -	115000	28240	440	40	15300	5490	17380	1680	—	47000
14, - - - - -	62000	17900	500	30	12600	4675	7900	1300	10200	7100
26, - - - - -	1070000	484000	1300	1400	473000	6800	4000	12000	28000	67000
38, - - - - -	64000000	2500000	230000	100000	38600000	30000	—	710000	—	—
50, - - - - -	250000000	130000000	—	1400000	97000000	—	—	2000000	450000	1900000
62, - - - - -	265000000	211000000	12000000	1400000	40000000	—	—	1000000	—	—

TABLE 18.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%	%
0, - - - - -	—	25.9	.3	.1	12.8	1.4	16.4	1.4	—	41.7
14, - - - - -	—	28.5	.9	—	20.0	8.1	12.2	1.8	15.8	12.7
26, - - - - -	—	45.0	.1	.1	43.8	.6	.4	1.1	2.6	6.3
38, - - - - -	—	37.5	.4	.1	61.0	—	—	1.0	—	—
50, - - - - -	—	50.6	—	.6	41.7	—	—	.8	.2	6.1
62, - - - - -	—	79.2	4.5	.6	15.3	—	—	.4	—	—

It will be noticed that these experiments were continued over a longer period than those already described. The purpose of this was to determine whether in milk that was more than twenty-four hours old the development of the bacteria was similar to that which has been described in the report upon ripening cream previously referred to (p. 26). It will be noticed from the tables given in the preceding pages of this article, that although there is considerable increase in the number of lactic bacteria in the first twenty-four hours, there is nothing that compares with the development of this class of organisms in ripening cream. In the present experiments the tests were continued until the milk was thoroughly sour or curdled, and the results are, therefore, parallel to those obtained in the study of ripened cream. As was to be expected, the milk that had not been iced soured and curdled quicker than the milk that had been kept for fourteen hours upon ice, the difference in the time of curdling being about fifteen hours. Thus the curdling was delayed about the length of time the milk was kept on ice. The first experiment was performed in the month of October, at a time when the weather was tolerably warm. The tables above give the results of the analyses, Tables 15 and 16 representing the milk which was placed immediately at 20° without icing, and Tables 17 and 18 those that were first iced for fourteen hours. It will of course be evident that the first of each pair of tables in this experiment, and, indeed, in all the subsequent experiments in this paper, are strictly parallel with those given in the first section, *i. e.*, a study of milk at 20°. They thus give additional evidence in regard to the development of bacteria in milk during the first few hours, when the milk is kept at a temperature of 20° C.

From the four tables above the following facts may be noted:

1. The multiplication of bacteria was much more rapid in the milk that had not been iced. This of course was to have been expected.

2. The number of bacteria which developed in the iced milk was far less than that in the non-iced milk, even at the time when the milk was curdled. As will be noticed in this experiment the iced milk at the time of curdling contained only about 300,000,000 per cubic centimeter, while the milk

that had not been iced contained 1,000,000,000 per cubic centimeter. This result is quite unexpected, and, although in strict accordance with previous and subsequent experiments, its significance is at the present time unknown. That the souring of milk is due to the growth of bacteria has been abundantly demonstrated, but why it is that at the time of curdling a sample of milk that has been previously iced contained only about one-third as many bacteria as a similar sample of milk that had not been iced is a question to which we can at present give no answer.

3. The icing of the milk appears to have an influence upon the species of bacteria that develop. As may be seen from the tables the iced milk contained up to the thirty-eighth hour a larger variety of bacteria than was present in milk that had not been iced. This may have been due, however, to the fact that the dilution was comparatively greater in the case of iced milk than in the case of the non-iced milk and, therefore, that a careful differentiation of species was more easily made.

4. The species *B. acidi lactici II.* was present in this sample of milk in considerable abundance and, as shown by the tables, increased more rapidly in the milk that had not been iced than it did in the iced milk. In the former there were 27 per cent. at the time of curdling, in the latter only 4.5 per cent. The icing thus apparently checked the development of this particular species.

5. The icing apparently had no influence upon *B. aerogenes*, which continued slowly to develop in numbers in both samples of milk, but in no case became over 1 per cent. of the whole.

6. The *Streptococcus* group developed in absolute numbers and in proportionate numbers for thirty-eight hours and afterwards decreased. The increase in numbers and proportions for the first period of the experiment is in accordance with the results given on previous pages. The decrease in the numbers in the later periods is interesting and suggestive. It will be seen further that the numbers of streptococci in this experiment were large, in one case being no less than 61 per cent. This large number was noticed in both the iced and the non-iced milk. In the milk that had not been iced, however, the numbers then fell off rapidly, and in the iced milk they also fell off

rapidly though they remained in larger numbers at the end. The last analyses of the iced milk showed the presence of 15 per cent. of these streptococci, while in the non-iced milk they had become reduced to less than one-half of 1 per cent.

7. The icing had apparently no influence upon the liquefiers, which were present in small proportions only in all the experiments.

8. It will be noticed that in the earlier tests there was a very large percentage of undetermined organisms. The reason for this appears to be in part because of the large numbers of streptococci. These organisms produce a slight alkaline reaction and when present in numbers neutralize the acid which is developed by the common lactic bacteria. In the first plate of the non-iced milk the presence of these alkaline colonies obscured the development of the lactic bacteria so that they could not be differentiated. The result was that nearly half of the colonies in this plate could not be determined; most of them were probably streptococci and the rest probably one of the lactic bacteria. It will be seen further that as the acid organisms increased in number the difficulty of separating them from the streptococci decreased and, finally, in the later plates all of the colonies were easily differentiated.

Experiment No. 9. November.—This experiment was practically a repetition of the last. The results were closely in accordance with those of the previous experiment. The following tables give the results.

TABLE 19.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 20° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina.	Liquefiers.	No. 220.	a	e	Acid liquefiers.	Undetermined.
0, - - -	23500	2125	—	—	7400	6575	2925	500	1825	1350	450	325
15, - - -	2000000	1345000	—	—	240000	6000	385000	—	—	—	—	23000
27, - - -	172000000	119000000	—	—	46000000	—	6500000	—	—	—	—	—
39, - - -	718000000	606000000	10000000	1200000	96000000	—	6000000	—	—	—	—	—
51, - - -	1234000000	1135000000	88500000	—	6000000	—	4700000	—	—	—	—	—

TABLE 20.

Percentages of bacteria of different species included in the total numbers above.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina.	Liquefiers.	No. 220.	a	e	Acid liquefiers.	Undetermined.
		%	%	%	%	%	%	%	%	%	%	%
0, - - -	—	9.1	—	—	31.8	24.7	12.0	2.1	8.1	5.6	1.8	4.8
15, - - -	—	68.8	—	—	12.3	.2	18.0	—	—	—	—	.7
27, - - -	—	69.8	—	—	26.5	—	3.7	—	—	—	—	—
39, - - -	—	84.0	1.5	.1	13.5	—	.9	—	—	—	—	—
51, - - -	—	91.8	7.3	—	.5	—	.4	—	—	—	—	—

TABLE 21.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk iced for 14 hours and then kept for different periods at 20° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina.	Liquefiers.	No. 220.	a	e	Undetermined.
0, - - - -	23500	2125	—	—	7400	6575	2900	500	1850	1350	1550
15, - - - -	78000	7350	—	—	28800	1950	29100	?	1800	?	9100
27, - - - -	750000	140000	—	—	294000	5000	144000	?	?	?	101250
39, - - - -	67000000	18000000	60000	—	37000000	?	4600000	?	?	?	6200000
51, - - - -	435000000	284000000	—	—	90000000	?	11100000	?	?	?	50000000
63, - - - -	692000000	478000000	98000000	400000	104000000	?	12000000	?	?	?	—

TABLE 22.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%	%	%
0, - - - -	—	9.1	—	—	31.8	24.7	12.0	2.1	8.1	5.6	6.6
15, - - - -	—	9.4	—	—	37.0	2.5	37.6	—	2.2	—	11.3
27, - - - -	—	20.9	—	—	43.8	.4	21.1	—	—	—	13.8
39, - - - -	—	26.8	.1	—	56.5	—	6.8	—	—	—	9.8
51, - - - -	—	65.1	—	—	20.6	—	2.5	—	—	—	11.8
63, - - - -	—	68.7	13.9	.1	14.9	—	2.4	—	—	—	—

From these tables the following detailed points may be noticed:

1. The preliminary icing of the milk for fourteen hours did not in this case produce a reduction in the number of bacteria as it did in the previous experiment. There was, at the end of the icing, an increase from 23,000 to 78,000.

2. It was found, however, that the number of bacteria developing in the iced milk never became as great, even at the time of curdling, as in the non-iced milk. The non-iced milk at the time of curdling contained nearly twice as many bacteria (1,200,000,000) as the iced milk (692,000,000). There was also a greater *rapidity* of multiplication of bacteria in the milk which had not been iced.

3. The variety of bacteria found in the iced milk was greater than that present in the milk that had not been iced.

4. This sample of milk contained at the outset apparently no representative of *B. acidi lactici II.* They made their appearance in the later stages and were found in both the iced and the non-iced milk.

5. The *Streptococcus* group was present in considerable numbers, and underwent an increase, in actual numbers and percentage, and a subsequent decrease. In this experiment, as in the last, this species decreased much more rapidly in milk that had not been iced. In the iced milk the percentage was at first almost 32, rose to 56, and then became reduced to 15 per cent. In non-iced milk the percentage decreased rapidly, so that at the close of the experiment there was less than .5 per cent. of this species of bacteria found, the total number being also less than in iced milk.

6. In this experiment the effect of icing seemed to be to increase the development of liquefying bacteria. The proportion of liquefiers in the iced milk rose to 37 per cent. and then dropped off rapidly. In the non-iced milk the percentage increased slightly and dropped off more rapidly, and at the end the liquefiers were much less abundant than in the iced milk.

7. In both samples of milk five of the varieties of bacteria, namely, the two *Sarcina* types and the species numbered 220, *a* and *e*, completely disappeared in the later tests. This of course

does not necessarily mean that they were absent, but that they had not increased sufficiently to make themselves evident in the plates.

8. As concerns actual numbers there was an increase in nearly all species of bacteria. In the non-iced milk, however, the actual numbers of the *Streptococcus* group increased for a while and then decreased; whereas in the iced milk the absolute number continued to increase to the end. In regard to the liquefiers the actual numbers also increased in the iced milk and the non-iced milk, but the increase after the first hours was very slight. In actual numbers, then, the liquefiers simply held their own, although decreasing in proportion.

From these two experiments the following general conclusions may be drawn:

1. In milk, as previously shown in cream, there is in later hours marked increase of lactic organisms which become so numerous as greatly to reduce the percentage of all other bacteria and apparently to cause some species actually to disappear. The percentage of lactic bacteria in these experiments was, however, not quite so high as in many samples of ripened cream previously described.*

2. The effect of a preliminary icing of about fourteen hours is greatly to reduce the number of bacteria which is to be found at any subsequent period. Although the milk eventually becomes acid and curdles, even at the time of curdling the number of bacteria is much reduced by the preliminary icing.

3. The effect of icing is to increase the probability of a development of the miscellaneous types of bacteria, whereas in milk that has not been iced these miscellaneous forms disappear more rapidly.

4. The icing of the milk appears to delay the period of decline of the *Streptococcus* group, and thus to increase the number of this species present at the end.

5. In regard to the other species the effect of the icing is only to delay the development, but not proportionately to modify it.

*Storrs Experiment Station Rept. 1900, pp. 13-33.

III. THE COMPARISON OF THE GROWTH OF BACTERIA AT 20 DEGREES CENTIGRADE AND AT 13 DEGREES CENTIGRADE.

Twenty degrees is a temperature higher than that at which milk is usually kept when it is intended for market. The milk dealer recognizes the value of low temperatures in preserving milk and commonly endeavors to reduce the temperature as rapidly and as low as possible to check the growth of bacteria, and hence to delay the spoiling of the milk. Our next series of experiments was designed for the purpose of determining with more accuracy, not only the value of a moderately low temperature in reducing the number of bacteria, but also the influence of such low temperatures upon the variety of bacteria which develop in the milk or which remained alive in the milk after exposure to low temperatures. For this purpose we have compared two samples of milk placed at different temperatures, and have studied in each case the development of the different species of bacteria. The method of experimentation was as follows:

The milk was obtained from the same barn as that from which most of the other samples described have been obtained. It was drawn directly from the cow into a sterilized vessel, brought to the laboratory and plates made from some of it immediately. The rest was then divided into two lots, one of which was kept at the ordinary temperature of 20° C., the temperature varying slightly in successive hours, and the other placed at a temperature of 13° C. This temperature was chosen as being approximately that which the milk dealers frequently attempt to obtain in their milk for the purpose of preserving it. A bacteriological examination was made of each of these samples at different intervals. The milk kept at 20° was plated, as in the above experiments, at intervals of about six hours for a period of twenty-four hours. Milk kept at 13° was not, however, tested so frequently. At the outset of the experiments we made the tests of this sample at the same intervals as the sample kept at 20°, but it was soon found that the development of bacteria was so very slow at the lower temperature that the series of plates showed practically no change from one test to another, the milk at the end of twenty-four hours being almost like the milk at the start. To decrease

the labor, therefore, in later experiments we made our examinations of the milk kept at 13° at longer intervals; in the records of experiments which follow it will be seen that the cooled sample of milk was tested once in twelve hours, and the tests were continued for a period of about fifty hours, thus making the number of tests in the two samples of milk identical. The tests are thus of course not strictly parallel with each other in the two samples because they were made at different intervals; but it is impossible to make exactly parallel tests. The conditions of the milk kept at the two temperatures is so unlike that there was no time in the whole experiment where the one sample could, from a bacteriological standpoint, be compared with the other.

Several of the earlier experiments in this line were quite unsatisfactory because of improper understanding of these conditions. The milk which was kept at the temperature of 13° was, in the early experiments, diluted very much too highly, inasmuch as we anticipated a greater growth of bacteria than occurred. Tests were also made too frequently, and other difficulties appeared, so that our first experiments were quite unsatisfactory as concerns any comparison between the milk at 20° and the milk at 13°. These experiments are not reported here; the only ones which are given are those performed after we had learned sufficient about the results to be able to plan the experiment a little more satisfactorily.

Experiment No. 10. January.—Tables 23–26 show the results that were obtained in this experiment. The preliminary test of fresh milk was unsatisfactory because of the presence of too large a number of liquefiers.

The most suggestive facts to be noticed from these tables are as follows:

1. Perhaps the most extraordinary and surprising feature is seen in the comparison of the total numbers of bacteria in the two samples of milk. In the sample kept at 20° the number increased regularly, reaching 18,000,000 in the course of twenty-eight hours. It was to be expected that the number

TABLE 23.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 20° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Rapid liquefiers.	Slow liquefiers.	No. 219.	No. 220.	f	a	No. 217.	Undetermined.
0, -	Test ruined by liquefiers and moulds.														
6, -	87500	3550	—	—	11000	7200	—	—	9250	6000	9450	12600	800	—	27600
14, -	574000	59500	—	—	91000	15700	9800	—	160000	23700	—	—	—	—	214500
21, -	1500000	224000	—	3000	353000	19400	2500	—	740000	5500	75000	—	6000	—	80500
28, -	18000000	3000000	2300000	70000	2500000	90000	212000	157000	3510000	2350000	—	—	—	60000	4000000

TABLE 24.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%	%	%	%	%	%	%
0, -	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6, -	—	4.0	—	—	12.5	8.2	—	—	10.6	6.9	10.8	14.5	.9	—	31.6
14, -	—	11.0	—	—	15.9	3.5	2.0	—	27.4	4.3	—	—	—	—	35.9
21, -	—	15.2	—	.5	24.0	1.4	.6	—	51.2	.4	.5	—	.4	—	5.8
28, -	—	16.2	12.7	.4	13.9	.5	1.2	.9	19.6	12.8	—	—	—	.4	21.4

TABLE 25.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 13° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Rapid liquefiers.	Slow liquefiers.	No. 219.	No. 220.	a	g	No. 217.	Undetermined.
0, - - -	Test ruined by liquefiers and moulds.														
16, - - -	143700	29900	—	—	23300	11700	5700	—	9100	12500	24100	—	—	—	27400
28, - - -	103300	2800	—	—	1300	57500	700	—	7000	900	9100	—	—	—	24000
40, - - -	111000	2300	—	—	22000	18500	10000	—	16500	16000	18500	—	6000	500	1700
52, - - -	250000	8000	—	800	69000	113000	4100	3100	38000	2200	10000	200	—	500	—

TABLE 26.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%	%	%	%	%	%	%
0, - - -	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16, - - -	—	21.0	—	—	16.1	8.2	4.0	—	6.3	8.5	16.7	—	—	—	19.2
28, - - -	—	2.7	—	—	.9	55.7	.7	—	6.8	.9	9.1	—	—	—	23.2
40, - - -	—	2.1	—	—	19.3	15.7	9.1	—	15.2	14.9	16.0	—	5.8	.3	1.6
52, - - -	—	3.3	—	.3	27.7	43.9	1.6	1.3	14.8	2.5	3.9	.5	—	.2	—

in the milk kept at 13° would be less, but the figures in the first column of Table 25 are very surprising. There was from the sixteenth hour to the twenty-eighth hour, a period of twelve hours, a decrease of 40,000; in the next twelve hours an increase of about 11,000; and in milk which was fifty-two hours old the number of bacteria was not quite twice as great as it was in milk sixteen hours old. In other words, there was practically no increase in total numbers of bacteria during the period of nearly forty hours covered by the experiment. This being the case, it was evident that we might expect to find a considerable variation in the proportions of the different species, for it is quite likely that some species would be found to be favored by such low temperatures and would develop, while others would be unfavorably affected. This expectation is entirely borne out by the results, as shown in the tables on pages 59 and 60. The variations shown in the different species are as follows:

2. The common *B. acidi lactici* apparently failed to develop at 13°. Indeed, at first it rapidly decreased in numbers. At sixteen hours there were present about 30,000, 21 per cent. of the whole. There was no further development of this species; in fact, the number fell off in the next twelve hours; and in milk fifty-two hours old it was only 8,000, a little over a fourth of what it was originally, and the proportion only about 3 per cent.

3. While the temperature of 13° was manifestly unfavorable to the development of *B. acidi lactici*, it was on the other hand favorable to the development of the *Streptococcus* group, which rose from 16 per cent. to 28 per cent. If this is compared with the development at 20° it will be seen that the *Streptococcus* group has been favored by the low temperature more than by the high temperature, since in the sample at 20° there were only about 14 per cent. of these organisms.

4. At 13° there is seen an unusual development of *Sarcina I*. This micro-organism, which was present in the milk kept at 20° in a proportion of only about 2 per cent., increased extraordinarily in the sample kept at 13°, appearing in the last test as high as 44 per cent. The large number given in the test made at twenty-eight hours, 55 per cent., is probably an error, due perhaps to a failure to differentiate *Sarcina* and the *Streptococcus;* the other figures are probably reliable.

5. It will be noticed that the higher temperature apparently favored the development of liquefiers, which rose from 10 per cent. to 51 per cent. in twenty-one hours at 20°, but at 13° reached only 15 per cent., even at the highest point of development.

6. One especially striking effect of the low temperature is the increase in the variety of bacteria. In all the experiments described on preceding pages, as well as in those on later pages, it will be seen that at a temperature of 20° there is commonly a decline in the number of varieties of bacteria found in the milk, so that in the later hours the number is less than at first, and in the milk which is forty to sixty hours old the number of species has commonly become reduced to two or three. In the milk kept at 13°, however, the reverse is the case. As can be seen by Table 25 the milk at fifty-two hours has a greater variety of species than the fresh milk and these species are present in considerable numbers even at the end. In other words, this experiment would seem to indicate that whereas at the temperature of 20° the development of the acid organisms is stimulated to such an extent that they eventually take the place of most other species of bacteria in the milk, at a temperature of 13° the acid organisms are so held in check that the miscellaneous species of bacteria which are present in small numbers have an abundant chance to develop.

Experiment No. 11. January 24.—In this experiment the tests of the sample of milk which was kept at 20° were not satisfactory because in one test the set of plates developed numerous liquefiers, and in another test the set was broken. The only reliable test was that made of the fresh milk. The sample of milk which was kept at 13°, however, was carried through a series of tests, all of which were satisfactory. The results given in Tables 27 and 28 are of interest, even though it is not possible to compare them with results for the same sample of milk kept at 20°.

From the tables on page 63 the following facts may be noted:

1. Here, as in the previous experiment, the extremely slow development of the total number of bacteria is very striking, at the end of fifty-two hours there being in all only 67,000. From the time of the first test to that made at the end of forty

TABLE 27.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 13° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Rapid liquefiers.	Slow liquefiers.	No. 219.	No. 220.	a	Undetermined.
0,	20000	?	—	—	280	12600	2280	130	2200	400	3300	—	—
16,	15500	300	—	—	400	9500	1000	?	1750	300	2300	—	—
28,	19000	925	—	—	100	11100	750	350	1700	575	3900	25	—
40,	21300	950	—	—	225	10800	975	700	2600	250	4800	—	—
52,	67800	9800	—	—	18800	1000	?	7300	19600	600	5700	—	4000

TABLE 28.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%	%	%	%	%
0,	—	—	—	—	1.3	62.5	6.3	.6	10.8	1.9	16.6	—	—
16,	—	2.2	—	—	2.7	60.7	6.2	—	11.4	2.0	14.8	—	—
28,	—	4.7	—	—	.5	57.4	3.9	1.8	8.8	2.9	19.9	.1	—
40,	—	4.0	—	—	.9	50.3	4.7	3.1	12.4	1.2	23.4	—	—
52,	—	14.5	—	—	27.7	1.3	—	11.2	29.2	.8	9.0	—	6.3

hours, as will be seen by the first column in Table 27, there was no increase of bacteria. The next twelve hours showed considerable increase. There was, however, a slight change in the variety of bacteria which appear in the successive analyses.

2. A slight increase in the number of *B. acidi lactici* may be noticed in the first forty hours, and a considerable increase in the last twelve hours.

3. The *Streptococcus* group remained practically unchanged in numbers during the first forty hours, but increased during the last twelve.

4. The most peculiar characteristic of this sample of milk was the high numbers of *Sarcina I.* In the fresh milk 62 per cent. of the bacteria were of this species, and for the first forty hours the number remained nearly constant, there being a slight falling off both in total numbers and in percentage. In the last twelve hours, when the lactic organisms and the *Streptococcus* increased in numbers, the *Sarcina* dropped off markedly, and in the last test were few in numbers.

5. It will be noticed that this sample shows a very high percentage of No. 220. This is a lactic organism closely related to *B. acidi lactici*, and having many of the characteristics of that more common species, but differing from it very sharply in its characteristic colony. It will be seen that in this sample of milk this lactic organism developed, in both numbers and percentage, during the forty hours when the other species were practically constant, but that in the last twelve hours it increased in numbers parallel with the increase in the number of other lactic organisms.

6. The chief difference between this sample at 13° and the one given in Table 25 is in the total failure of most bacteria to grow for forty hours, in the failure of the *Streptococcus* to develop until the last twelve hours, and in the great numbers of *Sarcina*.

Experiment No. 12. January 28.—This experiment, which was an exact repetition of the last, four days later, was successful throughout, and the results given in the following tables are quite reliable.

SAMPLE KEPT AT 20 DEGREES.

The study of the results with milk kept at 20°, given in Tables 29 and 30, shows nothing especially different from the

TABLE 29.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 20° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Rapid liquefiers.	Slow liquefiers.	No. 219.	No. 220.	f	Undetermined.
0, - - -	13500	700	—	—	6800	100	?	225	2275	300	2050	—	1025
6, - - -	9175	1050	—	50	1900	450	200	75	1050	1150	1725	400	1125
19, - - -	34900	2850	—	150	13100	1300	900	1550	8250	800	—	2900	3150
26, - - -	607500	50000	—	?	211800	?	—	41800	198000	55000	—	49600	—
32, - - -	9200000	1930000	—	77000	1120000	?	—	883000	1280000	650000	—	2760000	58000

TABLE 30.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%	%	%	%	%
0, - - -	—	5.2	—	—	50.5	.7	—	1.7	16.9	2.2	15.2	—	7.6
6, - - -	—	11.5	—	.5	20.8	5.0	2.1	.8	11.4	12.3	18.5	4.3	12.8
19, - - -	—	8.4	—	.4	36.4	3.6	2.6	4.3	24.5	2.0	—	7.8	10.0
26, - - -	—	8.4	—	—	34.9	—	—	7.0	32.8	8.8	—	8.1	—
32, - - -	—	20.9	—	.8	11.8	—	—	9.6	13.9	7.1	—	29.6	6.3

TABLE 31.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 13° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Rapid liquefiers.	Slow liquefiers.	No. 219.	No. 220.	g	a	Undetermined.
0, - - - - - - -	13500	700	—	—	6800	100	—	225	2275	300	2250	—	—	1025
15, - - - - - - -	11250	925	—	25	3550	?	—	50	1950	1025	1675	—	25	2025
27, - - - - - - -	10450	1800	—	25	3350	300	125	75	925	2000	1525	125	—	250
40, - - - - - - -	5975	800	—	—	1975	—	—	1000	1025	475	—	700	—	—
51, - - - - - - -	62000	4200	—	—	28600	4050	—	12250	10425	2325	—	—	—	—

TABLE 32.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%	%	%	%	%	%
0, - - - - - - -	—	5.2	—	—	50.5	.7	—	1.7	16.9	2.2	15.2	—	—	7.6
15, - - - - - - -	—	9.1	—	.2	31.2	—	—	.6	17.2	10.7	15.1	—	.2	15.7
27, - - - - - - -	—	18.6	—	.3	31.0	2.8	1.2	.8	8.9	19.7	13.4	1.3	—	2.0
40, - - - - - - -	—	12.1	—	—	32.6	—	—	17.8	16.8	7.4	—	13.3	—	—
52, - - - - - - -	—	6.7	—	—	46.1	6.6	—	19.8	17.0	3.8	—	—	—	—

results shown by the previous tables. It will be noticed, however, that there was an exceptionally large number of the species No. 220, which was the same organism that appeared in the last series of experiments. This organism was found in the first two tests in large numbers, but in the later tests did not appear. It is possible that the presence of this new organism was associated with the fact that in this experiment, as in the last, the animals were fed from a different lot of hay, which might very likely have contained some species of organisms differing from those previously found, which would explain the appearance of this No. 220 in such large numbers.

SAMPLE KEPT AT 13 DEGREES.

1. There was noticed, as before, in the milk kept at 13°, no increase in total number of bacteria for forty hours; indeed, the sample at the end of forty hours contained not quite half as many as the fresh sample of milk. In the next twelve hours there was, as in the previous experiments, an increase in total number of bacteria. It will be seen further that this increase that occurred between forty and fifty-two hours was due chiefly to the development of the *Streptococcus* and liquefying organisms.

2. The most striking difference between this and the last experiment is seen in the growth of the *Sarcina*. Whereas in the experiment of January 24th this species was present in the first forty hours in large numbers, over 50 per cent. of the whole, in this sample there were present at the outset only .7 of a per cent.—about 100 per cubic centimeter—and in the subsequent tests the presence of this species was doubtful, until the last one when they increased in numbers slightly.

3. The liquefiers remained throughout this series of plates in about the same relative proportions, varying somewhat in different tests and increasing considerably in the last twelve hours.

4. The acid organism No. 220, present in the first plates, disappeared entirely from the later tests in this experiment, whereas in the last experiment this species continued to be present up to the end of forty hours.

Experiment No. 13. February 4.—This experiment is a repetition of Experiments Nos. 11 and 12. The results are shown in Tables 33–36 following:

TABLE 33.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 20° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Rapid liquefiers.	Slow liquefiers.	No. 219.	No. 220.	g	a	h+i	Undetermined.
0,	34000	850	—	25	4600	6750	3550	?	2850	975	10400	2075	—	—	2250
6,	24875	500	—	50	8200	1200	4800	25	2600	1800	4800	400	—	—	525
15,	189000	23300	—	3400	73200	9500	3300	950	26600	11000	200	—	1200	—	35800
18,	809800	106000	—	6900	204400	22500	17000	15000	361000	10000	6900	—	—	—	59000
29,	7000000	2107000	—	60000	2276000	338000	235000	238000	1238000	150000	—	—	—	15000	358000

TABLE 34.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%	%	%	%	%	%	%
0,	—	2.5	—	.1	13.4	19.7	10.3	—	8.3	2.9	30.2	6.1	—	—	6.5
6,	—	1.7	—	.2	34.7	4.5	18.4	.2	10.6	7.5	19.0	1.4	—	—	1.8
15,	—	12.8	—	2.1	39.8	4.7	1.8	.5	14.8	5.5	.1	—	.7	—	17.2
18,	—	13.3	—	.7	26.0	2.7	2.0	1.9	44.2	1.4	.7	—	—	—	7.1
29,	—	29.8	—	.8	32.8	4.7	3.4	3.4	18.0	2.1	—	—	—	.3	4.7

Table 35.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 13° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogeues.	Streptococcus.	Sarcina I.	Sarcina II.	Rapid liquefiers.	Slow liquefiers.	No. 219.	No. 220.	g	e	Undetermined.
0, - - - - -	34000	850	—	25	4600	6750	3550	?	2850	975	10400	2075	—	2250
15, - - - - -	26700	1300	—	—	4100	4350	2500	75	2025	1375	6400	1300	—	3275
27, - - - - -	20800	950	—	—	1850	4200	2900	150	1900	1200	5400	—	1100	1150
40, - - - - -	61000	7100	—	425	30300	?	?	925	12900	4900	?	—	—	4500
52, - - - - -	573000	27800	—	—	400000	?	?	13000	89500	13500	?	—	—	13500

Table 36.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%	%	%	%	%	%
0, - - - - -	—	2.5	—	.1	13.4	19.7	10.3	—	8.3	2.9	30.2	6.1	—	6.5
15, - - - - -	—	4.6	—	—	16.0	15.7	10.2	.3	7.1	5.7	23.2	5.0	—	12.1
27, - - - - -	—	4.5	—	—	9.6	20.0	13.6	.8	8.8	6.8	25.6	—	3.7	5.7
40, - - - - -	—	11.8	—	.7	49.5	—	—	1.5	21.2	7.9	—	—	—	7.4
52, - - - - -	—	5.0	—	—	69.5	—	—	2.4	15.6	5.1	—	—	—	2.4

The most significant features shown by the preceding tables are as follows:

SAMPLE KEPT AT 20 DEGREES.

1. In the sample of milk maintained at 20° there was a noted falling off in the number of *Sarcina* species during the first six hours, from which time the number remained constant in percentage though increasing regularly in total numbers.

2. The liquefying bacteria showed for the first eighteen hours a constant increase in percentage and total numbers, the percentage reaching 44 at the end of the eighteenth hour; in the next six hours it dropped to 18. The total number, however, increased until the end of the experiment.

3. The species No. 220 was found in the fresh milk in very unusual quantity, but it dropped very rapidly, the milk at six hours containing only 19 per cent., and in later experiments practically disappeared.

SAMPLE KEPT AT 13 DEGREES.

1. In the milk retained at 13° the total numbers showed essentially the same variations as in earlier experiments, the number remaining without increase for about thirty hours, although by the fortieth hour a considerable increase was seen, and by fifty-two hours the number had become larger than in any other of the samples of milk kept at the same temperature.

2. The *B. acidi lactici* remained throughout the experiment with practically no change in percentage, but with an increase in total numbers in the last two tests.

3. The *Streptococcus* group showed here the most unusual relations, inasmuch as in the last two tests the numbers increased prodigiously, rising to about 70 per cent. in the milk which was fifty-two hours old. This great increase in this old sample of milk was somewhat unusual, although something similar has been found in some other experiments. The increase in total numbers was also very great.

4. The species of *Sarcina* played no part in the changes that must have taken place in this milk. They were present in considerable quantity and moderate percentage at the start, but disappeared from the plates by the fortieth hour, and were therefore present, if at all, only in small numbers.

5. The liquefiers played little part in the experiment, their numbers remaining practically constant so far as concerns percentage, though the total number increased with some regularity.

6. The other three miscellaneous species given in the tables either disappeared during the experiments, or became so small in numbers as not to be noticeable in the later tests.

7. The chief change which occurred in the bacteria in the sample of milk retained at 13° was the extraordinary multiplication of the *Streptococcus* group. Beginning somewhere between the thirtieth and the fortieth hour, this bacterium multiplied very rapidly, increasing the total numbers of bacteria more than tenfold and producing a corresponding decrease in the percentages of all other species. The other species of bacteria remained without any considerable increase during the whole experiment.

Experiment No. 14. February 10.—The conditions of this experiment were identical with those of the preceding. The results are shown in the following tables:

TABLE 37.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 20° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Rapid liquefiers.	Slow liquefiers.	No. 219.	No. 220.	a	No. 217.	Miscellaneous	Undetermined.
0,	6525	825	—	50	1225	75	50	25	2025	500	525	325	50	625	175
6,	5650	1200	—	75	1175	425	150	?	1125	650	450	225	50	125	—
14,	19200	3150	1750	—	2675	?	375	?	6100	1125	450	675	600	2000	350
21,	645600	143000	41900	—	45000	1900	?	10600	358000	6200	?	?	1900	?	37500
26,	6275000	2000000	1200000	45000	297500	?	15000	52500	2250000	?	?	5000	15000	21000	402500

TABLE 38.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%	%	%	%	%	%	%
0,	—	13.0	—	.7	18.9	1.1	.8	.4	30.8	7.9	8.1	5.0	.7	10.1	2.5
6,	—	21.4	—	1.3	20.9	7.7	2.8	—	19.8	11.5	7.9	3.7	.8	2.2	—
14,	—	16.0	9.7	—	13.1	—	1.7	—	30.5	5.8	2.9	3.2	3.9	11.6	1.6
21,	—	22.4	6.3	—	7.1	.3	—	1.7	55.7	.9	—	—	.3	—	5.9
26,	—	32.6	17.6	.5	5.0	—	.2	.9	35.7	—	—	.1	.3	.3	6.8

TABLE 39.

Total number of bacteria, and number of organisms of different species, per cubic centimeter in milk kept for different periods at 13° C.

Age of milk in hours.	Total number of bacteria.	B. acidi lactici I.	B. acidi lactici II.	B. aerogenes.	Streptococcus.	Sarcina I.	Sarcina II.	Rapid liquefiers.	Slow liquefiers.	No. 219.	No. 220.	a	No. 217.	Miscellaneous
0, - - - - - -	6525	825	50	50	1225	75	50	25	2025	500	525	325	50	800
12, - - - - - -	4375	775	—	25	700	825	150	50	1025	450	150	25	75	125
25, - - - - - -	6425	1600	1180	?	1060	275	15	80	900	650	120	150	30	350
38, - - - - - -	29000	2950	19300	?	2025	125	250	275	2025	1125	150	150	150	1000
50, - - - . - -	140200	11000	101000	?	4150	206	200	3050	5000	2550	200	—	600	15200

TABLE 40.

Percentages of bacteria of different species included in the total numbers above.

		%	%	%	%	%	%	%	%	%	%	%	%	%
0, - - - - - -	—	13.0	.7	.7	18.9	1.1	.8	.4	30.8	7.9	8.1	5.0	.7	11.9
12, - - - - - -	—	17.9	—	.5	16.4	19.0	3.6	1.1	23.6	9.9	3.2	.6	1.5	2.7
25, - - - - - -	—	25.0	18.6	—	16.7	4.2	.2	1.2	14.2	10.0	2.0	2.1	.4	5.4
38, - - - - - -	—	9.5	65.1	—	7.4	.4	.8	.9	6.7	4.2	.5	.5	.5	3.5
50, - - - - - -	—	5.6	73.8	—	3.1	.1	.1	2.3	3.5	1.6	.1	—	.3	9.5

SAMPLE KEPT AT 20 DEGREES.

1. The most striking feature in these tables is the very large number of species of bacteria. There are tabulated twelve different species, and a thirteenth column includes at least five other species, easily differentiated, but tabulated together in one column.

2. There was a regular decrease in the percentage of the *Streptococcus* group, though a slow increase in total numbers.

3. The liquefying bacteria showed a regular increase in percentage and numbers for the first four tests, reaching 55 per cent. at twenty-one hours, and then a decrease in the last test.

4. From these facts it appears that the large increase in numbers occurring between the twenty-first and the twenty-sixth hour was due to the exceptionally rapid growth of *B. acidi lactici I. and II.* In other words, the lactic organisms had at this time begun to grow at the expense of the other species, as previous experiments have shown that they always do in older samples of milk.

SAMPLE KEPT AT 13 DEGREES.

1. As before there was seen a complete absence of increase in total numbers for over thirty hours. By the thirty-eighth hour, however, there was a slight increase and by the fiftieth hour a considerable increase in total numbers.

2. *B. acidi lactici* played little part in the increase in numbers, for, though more abundant in the last tests than in the others, its percentage was much less than in earlier samples.

3. *B. acidi lactici II.* had a very unusual development in this sample of milk. It was present in small numbers in the original sample, began to increase apparently about the twenty-fifth hour, and then developed very rapidly, reaching nearly 74 per cent. in the last sample of milk.

4. The *Streptococcus* group underwent a constant decline in percentage, with a very slight increase in total numbers.

5. The two *Sarcina* species remained without increase during the whole experiment.

6. The liquefiers failed to develop in this sample, being present only in small numbers at the end.

7. The miscellaneous species, which were numerous, continued to remain through the whole experiment in about equal numbers, nearly every plate made showing most of these species present in small numbers and in small percentage. In other words, in this experiment the development of the lactic organisms did not, as usual, result in the decrease of the miscellaneous species.

8. From these facts it is seen that the increase in numbers occurring from the thirty-eighth to the fiftieth hour was due to the excessive growth of *B. acidi lactici II.*, which resulted in a marked relative decline in percentage of all the other species present.

SUMMARY OF THE EFFECT OF PRESERVING THE MILK AT 13 DEGREES.

1. A temperature of 13° has an unexpected effect upon the total number of bacteria, as can be seen from the results given in the foregoing tables. For a period of from thirty-six to thirty-eight hours the bacteria fail to grow at all, and may at this time be actually less in numbers than at the outset. This phenomenon is similar to that which occurs in milk at 70° for six hours, and may perhaps be regarded as a continuation of the so-called "germicidal action" of the milk. After about forty-eight hours the number of bacteria begins to increase, but even at fifty hours, the limit of our experiments, the number is very small. It will be seen that at fifty hours the number of bacteria in milk kept at 13° is no more than is present at eighteen hours in milk which is preserved at 20°.

2. After about the fortieth hour the growth of bacteria begins, but it is seen that some of the species of bacteria are different from those which develop in milk which is kept at 20°.

3. The action of this temperature is apparently to check very decidedly the growth of *B. acidi lactici*, which, although not killed, remains even to the end of the experiments, as a rule, in small numbers, and is hardly more abundant at the end of the experiment than at the beginning. There is commonly a slight increase in numbers in the last twelve hours.

4. The growth which occurs after forty hours is due usually to the *Streptococcus* group increasing in numbers, sometimes to the *B. acidi lactici II.*, and, in our experiments in one case only, to the development of *B. acidi lactici I.*

5. During the first forty hours there are slight fluctuations in the species of bacteria which are found at different tests. The *Streptococcus* group regularly increases in total number and percentage. Liquefiers frequently increase. The *Sarcina* species in one case increased slightly, but usually remains about constant, or sometimes decrease in numbers. The miscellaneous bacteria remain in about equal quantity throughout the first forty hours. All of this simply means that for this period there is very little change in the bacteria, but that the *Streptococcus* appears to be able to grow at this temperature rather more readily than the other species.

6. In general it thus appears that a temperature of 13° affects not only the total numbers of bacteria but also the species which develop.

7. It appears that from a standpoint of the number of bacteria which are present in milk at any age, the question of temperature is a factor of more significance than the question of the original contamination.

SUMMARY.

It is well now to summarize briefly the general results which have been obtained from the experiments described in the previous pages. They are essentially as follows:

1. There was little regularity in the comparative development of the species present in milk. Numerous irregularities were observed in different experiments which are inexplicable by any data as yet in our possession, and many differences in growth were found in different samples of milk kept under apparently identical conditions.

2. The number of bacteria which are present in fresh milk gives no indication as to the number that may be present in later hours. It frequently happens that milk which at the outset has small numbers will in later hours have numbers considerably larger than those in other samples of milk which at the outset contained more bacteria, even though the two samples of milk are kept under identical conditions.

3. The question of temperature is a matter of more significance in determining the number of bacteria which are present at any stage than the question of the original contamination of the milk.

4. In the general changes which occur in the species present in milk two stages are clearly seen, which are not, however, sharply marked off from each other. The first is the period of the first few hours, when the number of bacteria is less than about 10,000,000. This period lasts, in milk kept at 20°, for about twenty-four hours, but if kept at 13° it lasts for about fifty hours or even more. The second period is that in which the total number of bacteria is over 10,000,000, and from this up to the time of curdling.

FIRST PERIOD.

5. For a number of hours after the milk is drawn from the cow there is no multiplication of bacteria, but, on the contrary, frequently an actual reduction in numbers. This has been pointed out before and has been called a "germicide property," lasting for a varying length of time up to forty hours, the length of time depending somewhat upon temperature. After the first six hours at 20° most species of bacteria begin to increase in absolute numbers; some, however, remain without any appreciable growth and others seem to disappear, not being found in the later analyses. This means, at all events, that they do not materially develop in numbers, although they may not actually be destroyed.

6. At 20° there is a uniform increase in B. acidi lactici during the first period of twenty-four hours. The total numbers increase regularly and the percentage also increases, sometimes reaching 50 per cent. in the course of twenty-four hours, although more commonly it is far less, from 10 to 30 per cent.

7. At 20° the other lactic bacteria are, in milk in this region, irregular in their development. B. acidi lactici II. occurs in fresh milk only rarely. It is occasionally found in some quantity at the end of twenty-four hours but is not usually of much importance. B. aerogenes is found with more or less regularity, but never in very large numbers. In the numerous samples of milk which we have tested this organism is rarely present in proportions greater than 2 to 3 per cent.

8. At 20° the Streptococcus group always increases during the first period of twenty-four hours. The absolute numbers show a constant increase and frequently, though not always, the proportionate numbers also increase. This group is always very abundant at the end of twenty-four hours and, in many cases, is relatively more abundant than in earlier hours.

9. At 20° the development of liquefying bacteria is quite variable. There was practically always an increase in total numbers, and sometimes an increase in percentage, though frequently a decrease.

10. At 20° the two species of Sarcina developed only very slightly during the first period of ripening. They usually increase in actual numbers though they decrease in percentage and are never present in numbers sufficient to make them of much significance.

11. There is a general decrease in number of miscellaneous species. This is not very noticeable during the first twenty-four hours, though it frequently happens that some of the species present in small numbers at the outset fail to appear at the end of twenty-four hours.

12. At 13° the results are somewhat different. The most noticeable effect is that this temperature produces a lengthening of the original period of no growth, from thirty-six to forty hours, and, although at the end of forty hours the number of bacteria increases, they are, even at fifty hours, relatively very few, usually no more numerous than those present after eighteen hours in milk kept at 20°.

13. After forty hours at 13° there is a somewhat rapid growth of bacteria. This, however, is not due to the development of the common B. acidi lactici but usually to other species. Most frequently it appears to be the Streptococcus group that develops at this period.

14. The effect of the low temperature appears to be to check, at least for fifty hours, the growth of the common lactic organism, B. acidi lactici.

15. The effect of the low temperature appears to be to make it possible for the miscellaneous species of bacteria that may be present in the milk to remain in abundance a longer period.

16. The effect of a preliminary icing of the milk is also noticeable. When the milk is iced for a period of fifteen hours it produces several important results. The first is a decrease in numbers of bacteria and rapidity of bacteria growth. This is shown, not only by the fact that the milk at any particular hour contains fewer bacteria than the similar sample of milk which has not been iced, but also by the fact that the number which develops at the time when the milk curdles is very much less in samples of milk which have previously been iced.

17. The preliminary icing of milk increases the chances which the miscellaneous bacteria have of growing in the milk; for milk which has been iced shows even in late stages a larger number of miscellaneous organisms than a similar sample of milk which has not been iced.

18. The effect of the preliminary icing is to postpone the period when the B. acidi lactici develops in abundance and gains the ascendency over the other species of bacteria; in other words to delay the second period in the ripening.

SECOND PERIOD.

19. The second period is characterized by a very rapid development of total numbers of bacteria which increase more rapidly than in the first period. This great increase is due chiefly to the development of lactic organisms. B. acidi lactici I. in particular develops now with marvellous rapidity, and the B. acidi lactici II. is also found, in many cases, in great abundance. B. aerogenes, in our milk, rarely becomes very numerous. The acid organisms that develop during this second period sometimes reach 99 per cent. of the total bacteria, though commonly not so high as this.

20. Parallel with the increase in lactic organisms there is a decrease in the relative numbers of all other species. Not only do the other species decrease in relative numbers, but most of them decrease in absolute numbers. The liquefiers frequently disappear entirely, and the Streptococcus group, which is one of the most persistent, seems to disappear entirely in many samples of milk during the second period. The miscellaneous organisms certainly disappear from the analyses; and this may mean that they have been destroyed or merely that they are in such small numbers that they fail to appear in highly diluted plates.

21. The disappearance of the liquefying organisms and others explains the fact, frequently noticed by those who study milk, that the development of lactic bacteria in milk prevents putrefaction from taking place. In other words, the milk is protected from the action of putrefactive bacteria by the rapid development of the lactic bacteria.

22. In general the most striking features in regard to the development of bacteria are the constant and uniform increase of lactic bacteria in the total numbers as well as in percentage, and the corresponding decrease in percentage and, finally, in total numbers, of practically all other species.

A STUDY OF RATIONS FED TO MILCH COWS IN CONNECTICUT.

BY C. S. PHELPS.

The study of rations fed to milch cows by several farmers in this State discussed on the following pages is similar to that conducted during the winter of 1899–1900, a full account of which was given in the last (1900) Report of the Station. The objects of the experiment were (1) to study the kinds of rations in use by farmers; (2) to point out to farmers by means of simple tests on their herds the advantages of a more rational system of feeding than is in common use; and (3) to study the economy of feeding according to the yields of butter fat.

The studies of thirty-seven dairy herds made by the Station in coöperation with farmers in different parts of the State prior to 1900, covering a period of seven years, and described in previous Reports of the Station, have led to two general deductions in regard to the feeding practices of Connecticut dairymen. First, the tendency has been to pay too little attention to the proportion of protein used in feeding milch cows. Rations relatively low in protein have predominated, although narrow rations with liberal proportions of protein have generally proved more economical. Second, too little effort has been made to feed according to the productiveness of the cows; either the quantity of milk or the yield of butter fat would seem to be a more rational basis on which to calculate the ration than the live weight of the animal. The first of these deductions was dwelt upon in the summary of the experiments of five years given in the Annual Report of the Station for 1897. The second deduction was discussed in the Annual Report for last year (1900) and is further considered on the following pages in the report of the studies made during the winter of 1900–1901.

FEEDING ACCORDING TO YIELDS OF BUTTER FAT.

Four herds were included in the studies here reported, two tests, as usual, being made with each herd. The herds were lettered and the tests numbered consecutively with those of former years, namely, herd T, tests 59 and 61; herd U, tests 60 and 62; herd V, tests 63 and 65; and herd W, tests 64 and 66.

In each case the feeding in the first test was conducted according to the usual practices of the dairyman, the kinds and amounts of coarse fodders and grain feeds used being those he was using when the test began. As a common thing each farmer fed all his cows a uniform ration, although in some cases the amount of grain feeds used was varied slightly for the different cows according to whether they were fresh or well advanced in lactation. An account was kept of the kinds and amounts of feeds used and of the quantity of milk produced, the feeds were sampled and analyzed, and the percentage of fat in the daily milk of each cow was determined; in this way it was learned how much of each ingredient the cow was receiving per day and how much milk and butter fat she was producing.

In the second test the ration was proposed by the Station and was based upon the yields of butter fat. All the cows included in the test were arranged in groups according to the amount of butter fat per day yielded by each during the first test, and all the cows in a group were fed a uniform ration. The ration consisted of two parts, a basal portion and a supplemental portion. The basal portion consisted of coarse fodders, usually those available from the farm, and grain feeds either grown on the farm or purchased. These were used in such amounts and proportions as to supply approximately the same amount of protein as in the average ration used in the first test. The supplemental portion consisted of concentrated feeding stuffs, which generally were purchased. These were mixed, according to their composition, in such proportions as to furnish from .2 to .3 pound of protein for every pound of the mixture—called for convenience a protein mixture. This mixture was kept separate from the grain feeds used as part of the basal ration, so that it could be omitted or fed in varying amounts as desired. In feeding, all the cows in a test were given the same basal ration and some or all of the cows

received a supplemental ration of the protein mixture, the amount of the latter varying according to the yields of butter fat. The plan of grouping the cows according to yield and the daily quantity of protein mixture and of protein fed per cow in each group in 1900 were as follows:

TABLE 41.

Daily yield of butter fat per cow in the different groups, and amounts of protein fed.

Group.	Protein mixture fed.	Herd T.		Herd U.		Herd V.		Herd W.	
		Daily yield of butter fat.	Protein fed daily.	Daily yield of butter fat.	Protein fed daily.	Daily yield of butter fat.	Protein fed daily.	Daily yield of butter fat.	Protein fed daily.
	Lbs	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
A, - -	—	.50–.65	1.62	.50– .65	2.02	.50– .70	1.99	.50– .70	2.48
B, - -	1	.66–.80	1.88	.66– .80	2.29	.71– .90	2.22	.71– .90	2.70
C, - -	2	.81–.95	2.13	.81– .95	2.56	.91–.110	2.45	.90–1.10	2.91
D, - -	3	—	—	.96–1.10	2.84	1.11–1.30	2.69	—	—
E, - -	4	—	—	1.11–1.25	3.11	—	—	—	—

In each of two herds there were three groups, in one herd four groups and in one herd five groups. Group A in each herd was the one receiving only the basal ration. In two herds the cows included in this group were those producing .50–.65 pound of butter fat per day; in the two other herds those producing .50–.70 pound were put in group A. The daily quantity of digestible protein per cow in the basal ration varied somewhat for the different herds but was very uniform for all the cows in the same test. In two cases it was about 2 pounds, in one it was 1.6 pounds, and in the other 2.5 pounds.

THE DETAILED DATA OF DAIRY HERD TESTS OF 1900–1901.

The detailed data of the dairy herd tests for the winter of 1900–1901 are given in Tables 44–51 beyond. There are two tables for each herd. The first table gives the statistics of the herd, including the breed, age, and estimated weight of each cow, the number of months since last calf, and, when known, the number of months till due to calf. It also includes the average daily yield of milk and butter fat and the daily percentages of fat in the milk for the first and second tests. The

breeds of the different cows are indicated by the abbreviations given in the second column, as follows: J=Jersey; H=Holstein; A=Ayrshire; S=Swiss. The letter G before the designation for the breed signifies that the cow was a grade.

In the second table is given the average daily ration per cow as calculated for the whole herd in the first test and for the separate groups in the second test. It shows the weights and amounts of digestible nutrients in the coarse and the concentrated feeds used in the ration, the fuel value, the nutritive ratio, the total cost, and the net cost after deducting the estimated value of the manure. Above the second table for each herd are given the kinds and amounts of feeding stuffs used daily for the herd in the first and second tests.

The rations for the different groups were estimated on the basis of digestible rather than total nutrients. The digestible nutrients in the different materials fed were calculated from the total nutrients shown by analysis by use of factors (coefficients of digestibility). The proportions of nutrients in the materials used as determined by actual analysis are given in the tables in the article on analyses of fodders and feeding stuffs in another part of this Report. The coefficients of digestibility employed in the calculations of digestible nutrients are given in the table below; the factors for the different feeding stuffs included in this table are based upon the results of actual digestion experiments with those materials or are assumed from the results of experiments with similar materials; the factors for the various mixtures were calculated from those for the different ingredients of the mixtures and the proportions in which they are used.

The fuel values of the rations were computed by multiplying the number of pounds of protein and carbohydrates by 1860 and of fat by 4220 and taking the sum of the products as representing the number of calories of available energy in the ration.*

---

* Inasmuch as satisfactory factors for the computation of the fuel values of feeding stuffs for animals have not been established, factors used in calculating the fuel values of the foods of man are frequently employed, although it is understood that the results thus obtained may be far from the truth. The factors here given are the older ones which have been commonly used. Factors slightly smaller than these, based upon more recent and more complete data, have been lately proposed by this Station (Report 1899, p. 104). The older factors have been used again in this instance, however, in order that the figures given in the tables herewith may be directly comparable with those in preceding reports.

TABLE 42.

Coefficients of digestibility employed in calculating the digestible nutrients in the different feeding stuffs used in the rations.

KIND OF FEEDING STUFFS.	Protein.	Fat.	Nitrogen-free extract.	Fiber.
	%	%	%	%
* Corn meal,	60	92	93	58
* Wheat bran,	77	69	68	20
* Cotton seed meal,	88	93	64	32
* Corn and cob meal,	76	82	84	28
* Cream gluten meal,	84	98	88	33
* Chicago gluten meal,	89	93	93	33
* Hominy chop,	60	92	93	58
* Wheat middlings,	79	87	81	33
** National gluten feed,	86	87	84	66
*** Quaker oat feed,	78	84	77	26
* Corn stover,	45	62	61	67
* Oat hay,	53	61	52	44
* Corn and soy bean silage,	65	82	75	65
* Mixed hay,	58	48	59	60
* Timothy hay,	48	60	63	52
† Black grass,	58	48	59	60
‡ Grain mixture No. 1 used in test No. 61,	79	91	71	25
‡ Grain mixture No. 2 used in test No. 61,	85	95	77	29
‡ Grain mixture No. 1 used in test No. 62,	82	82	74	23
‡ Grain mixture No. 2 used in test No. 62,	85	89	77	26
‡ Grain mixture used in test No. 63,	77	74	76	22
‡ Grain mixture used in test No. 64,	82	91	81	40
‡ Grain mixture No. 1 used in test No. 65,	81	82	78	28
‡ Grain mixture No. 2 used in test No. 65,	86	89	80	46
‡ Grain mixture used in test No. 66,	83	84	75	26

The cost of the rations in the different experiments was calculated from the kinds and quantities of different materials used and the prices current during the season in which the experiments were made. The prices of feeding stuffs taken were averages of prices for ton lots quoted to the Station by dealers in several different cities in the State. Those for coarse fodders produced on the farms were estimated by the farmers themselves.

* See Report Storrs Experiment Station for 1897, A Study of Rations fed to Milch Cows, p. 22; and Nitrogenous Feeding Stuffs, p. 83.

** Assumed as Buffalo gluten feed.

*** Assumed as oat feed.

† Assumed as mixed hay.

‡ Computed from the assumed digestibility of the ingredients used in the grain mixture.

In calculating the values of the manure obtainable from the different rations the proportions of nitrogen, phosphoric acid and potash in the different materials used were estimated or assumed as closely as could be from the data available; and it was also assumed that 75 per cent. of these ingredients in the fodders and feeding stuffs would be recoverable in the manure.* The valuations per pound of these ingredients were taken from those estimated by the New England Experiment Stations for the year 1900–1901.†

The following table shows the average market price per ton of the different materials used and the estimated value of the manure obtainable from one ton.

TABLE 43.

Valuation of feeding stuffs used in estimating cost of rations fed milch cows in winter 1900–1901.

KIND OF FEEDING STUFFS.	Market price per ton of feeding stuffs.	Estimated value of the manure obtainable from one ton of feeding stuffs.
	$	$
Corn meal,	20.00	5.00
Quaker oat feed,	20.00	9.50
Pillsbury's fancy mixed feed,	22.00	9.00
Cotton seed meal,	26.00	19.00
Corn and cob meal,	15.00	4.00
Wheat bran,	20.00	8.00
Cream gluten meal,	26.00	14.50
Chicago gluten meal,	26.00	14.50
Hominy chop,	20.00	5.00
Wheat middlings,	20.00	8.00
National gluten feed,	24.00	14.50
Oat hay,	12.00	3.50
Timothy hay,	16.00	4.00
Mixed grasses,	14.00	4.00
Black grass,	12.00	4.50
Corn stover,	6.00	3.00
Corn and soy bean silage,	3.00	1.25

The details of the tests with the different herds during the winter of 1900–1901 follow.

* See Storrs Expt. Sta. Rept. 1896, pp. 92–93.
† See article on Field Experiments with Fertilizers in this Report.

TABLE 44.

Statistics of herd T during tests Nos. 59 and 61.

Ref. No.	Cows. Group and Breed.	Age.	Weight.	Mos. since last calf.	Due.	Test No. 59, Dec. 11 to 22, 1900. Daily Milk Flow.			Daily Pctg. Fat.			Daily Yield of Fat.			Test No. 61, Jan. 8 to 19, 1901. Daily Milk Flow.			Daily Pctg. Fat.			Daily Yield of Fat.		
						Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
		Yrs.	Lbs.			Lbs.	Lbs.	Lbs.	%	%	%	Lbs	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs	Lbs.	Lbs.
	Group A.																						
3	G. J., - -	2	700	6	May, 1901,	8.6	10.0	9.5	5.2	5.8	5.5	.47	.54	.51	9.6	11.0	10.4	5.2	5.9	5.6	.53	.63	.58
7	G. J., - -	5	700	9	Apr., 1901,	8.0	10.9	10.0	4.2	7.4	6.3	.34	.78	.63	8.0	10.2	9.0	6.2	7.2	6.7	.51	.71	.60
12	G. J., - -	5	800	6	Apr., 1901,	9.6	11.2	10.1	6.0	6.7	6.3	.59	.72	.64	9.7	12.1	10.5	6.2	7.0	6.6	.62	.83	.69
13	G. J., - -	12	700	7	Apr., 1901,	11.2	15.0	14.0	4.2	4.8	4.6	.54	.72	.64	14.4	16.2	15.5	4.8	5.2	5.0	.73	.81	.77
	Average, -	—	**725**	—	—	—	—	**10.9**	—	—	**5.7**	—	—	**.61**	—	—	**11.4**	—	—	**6.0**	—	—	**.66**
	Group B.																						
4	G. J., - -	4	700	8	Mar., 1901,	9.6	11.8	11.0	5.8	6.8	6.2	.60	.80	.68	12.6	14.3	13.2	5.6	6.0	5.8	.73	.83	.77
6	G. J., - -	4	700	3	July, 1901,	11.2	14.4	12.9	4.9	5.5	5.1	.58	.80	.67	13.0	14.3	13.7	5.1	5.8	5.5	.70	.83	.76
10	G. J., - -	7	850	9	June, 1901,	11.2	13.0	12.2	4.7	6.6	5.4	.54	.84	.66	11.2	12.6	12.1	5,5	6.8	5.8	.62	.80	.71
11	G. J., - -	4	750	3	Sept., 1901,	13.2	14.4	13.6	5.0	5.6	5.3	.69	.76	.72	14.6	15.6	15.2	5.1	5.7	5.3	.77	.83	.81
	Average, -	—	**750**	—	—	—	—	**12.4**	—	—	**5.5**	—	—	**.68**	—	—	**13.6**	—	—	**5.6**	—	—	**.76**
	Group C.																						
1	G. J., - -	4	750	1	Sept., 1901,	18.6	22.0	19.9	4.7	5.5	5.2	.89	1.21	1.03	18.8	21.0	19.9	4.9	5.6	5.2	.94	1.18	1.03
2	G. J., - -	5	750	7	Apr., 1901,	15.4	16.6	16.0	5.0	5.5	5.3	.78	.89	.85	15.6	16.8	16.2	5.0	6.2	5.6	.79	1.04	.90
5	G. J., - -	6	800	1	Sept., 1901,	14.8	16.6	15.7	5.2	5.8	5.5	.79	.91	.86	17.0	18.3	17.5	5.5	5.8	5.6	.94	1.03	.98
9	G. J., - -	6	850	2	—	17.8	20.0	18.7	4.7	5.4	5.1	.84	1.00	.96	16.6	20.0	18.4	5.3	5.8	5.5	.96	1.08	1.00
14	G. J., - -	3	750	2	Sept., 1901,	18.2	20.0	19.3	4.1	4.9	4.5	.79	.93	.88	18.2	20.2	19.4	4.6	5.0	4.8	.87	.99	.93
	Average, -	—	**780**	—	—	—	—	**17.9**	—	—	**5.1**	—	—	**.92**	—	—	**18.3**	—	—	**5.3**	—	—	**.97**
	Herd average,	—	**750**	—	—	—	—	**14.1**	—	—	**5.4**	—	—	**.75**	—	—	**14.7**	—	—	**5.6**	—	—	**.81**

AVERAGE DAILY RATION PER COW. HERD T.

Test No. 59. Oat hay 9.8 lbs., corn stover 8 lbs., cotton seed meal .5 lb., Quaker oat feed 3.3 lbs., wheat bran 2.1 lbs., corn meal 2.7 lbs.

Test No. 61. Basal: Corn stover 8 lbs., oat hay 8 lbs., and 8 lbs. of grain feeds mixed as follows: Quaker oat feed 150 lbs., wheat bran 300 lbs., corn meal 200 lbs., cotton seed meal 75 lbs., cream gluten meal 125 lbs. Supplemental protein mixture: Group B, 1 lb., and Group C, 2 lbs. of grain feeds mixed as follows: Cotton seed meal 100 lbs., Quaker dairy feed 100 lbs., cream gluten meal 100 lbs.

Table 45.

Average weight of food and digestible nutrients fed per cow per day with fuel value and cost in dairy herd tests Nos. 59 and 61.

[Average weight of herd 750 lbs.]

Kind of Food.	Amount fed per day.	Digestible Nutrients and Fuel Value.						Nutritive ratio.	Cost.	Value of obt'nble manure.	Net cost.
		Protein.	Fat.	Carbohydrates.			Fuel Value.*				
				Nitrogen-free extract.	Fiber.	Total.					
First Test No. 59.	Lbs.	Lbs.	Lbs	Lbs.	Lbs.	Lbs.	Cal.	1:	Cts.	Cts.	Cts.
Whole Herd.											
Concentrated food, -	8.6	1.12	.34	4.14	.14	4.28	11480	4.5	8.7	3.6	5.1
Coarse food, - -	17.8	.63	.27	4.63	2.99	7.62	16480	13.1	8.3	3.1	5.2
Total food, -	26.4	1.75	.61	8.77	3.13	11.90	27960	7.6	17.0	6.7	10.3
Second Test No. 61.											
Group A.											
Concentrated food, -	8.0	1.19	.34	3.71	.13	3.84	10790	3.9	8.6	3.6	5.0
Coarse food, - -	16.0	.43	.21	3.64	2.23	5.87	12600	14.7	7.2	2.7	4.5
Total food, -	24.0	1.62	.55	7.35	2.36	9.71	23390	6.8	15.8	6.3	9.5
Group B.											
Concentrated food, -	9.0	1.45	.40	4.03	.15	4.18	12160	3.5	9.8	4.3	5.5
Coarse food, - -	16.0	.43	.21	3.64	2.23	5.87	12600	14.7	7.2	2.7	4.5
Total food, -	25.0	1.88	.61	7.67	2.38	10.05	24760	6.1	17.0	7.0	10.0
Group C.											
Concentrated food, -	10.0	1.70	.45	4.36	.17	4.53	13490	3.3	11.0	4.9	6.1
Coarse food, - -	16.0	.43	.21	3.64	2.23	5.87	12600	14.7	7.2	2.7	4.5
Total food, -	26.0	2.13	.66	8.00	2.40	10.40	26090	5.6	18.2	7.6	10.6

* See foot note p. 84.

TABLE 46.

Statistics of herd U during tests Nos. 60 and 62.

Ref. No.	Cows. Group and Breed.	Age.	Weight.	Mos. since last calf.	Due.	Test No. 60, Dec. 26, 1900, to Jan. 5, 1901. Daily Milk Flow.			Daily Pctg. Fat.			Daily Yield of Fat.			Test No. 62, Jan. 21, to Feb. 2, 1901. Daily Milk Flow.			Daily Pctg. Fat.			Daily Yield of Fat.		
						Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
	Group A.	Yrs	Lbs.			Lbs	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
5	G. J., - -	12	800	3	Sept., 1901,	12.9	14.8	13.8	4.6	4.9	4.7	.59	.70	.65	12.5	14.5	13.6	5.0	5.3	5.2	.65	.75	.71
13	G. Hol., - -	3	700	6	Aug., 1901,	10.2	12.6	11.6	4.6	4.8	4.7	.48	.59	.55	11.9	13.9	12.8	4.9	5.1	5.0	.60	.71	.64
	Average, -	—	**750**	—	—	—	—	**12.7**	—	—	**4.7**	—	—	**.60**	—	—	**13.2**	—	—	**5.1**	—	—	**.68**
	Group B.																						
2	G. J., - -	6	700	7	Sept., 1901,	15.0	18.0	16.4	4.7	5.2	4.9	.74	.94	.80	15.8	17.5	16.6	4.6	5.6	5.3	.75	.94	.87
3	G. J., - -	8	800	6	July, 1901,	14.0	16.0	15.0	4.6	4.9	4.7	.66	.75	.70	14.2	15.1	14.5	5.0	5.4	5.2	.71	.82	.75
4	G. J., - -	4	650	4	Aug., 1901,	13.4	15.2	14.3	4.8	5.3	5.1	.68	.79	.72	13.5	15.0	14.0	5.3	5.7	5.4	.72	.80	.76
10	G. J., - -	4	700	5	Sept., 1901,	12.6	16.0	14.6	5.2	5.6	5.4	.67	.83	.78	13.6	15.7	15.0	5.4	6.3	5.7	.78	.93	.85
12	G. J., - -	3	650	7	Aug., 1901,	10.4	13.0	11.4	4.8	6.3	5.8	.57	.74	.66	10.8	12.7	11.9	6.0	6.6	6.3	.70	.82	.75
	Average,	—	**700**	—	—	—	—	**14.3**	—	—	**5.2**	—	—	**.73**	—	—	**14.4**	—	—	**5.6**	—	—	**.80**
	Group C.																						
6	G. J., - -	5	750	4	Aug., 1901,	18.4	20.4	19.3	4.4	4.9	4.6	.86	.93	.90	17.8	21.3	20.1	4.4	5.6	5.0	.88	1.07	1.00
7	G. J., - -	6	750	2	Sept., 1901,	17.2	19.6	18.6	4.4	5.1	4.9	.84	.97	.90	18.6	20.8	19.6	5.1	6.1	5.5	.94	1.22	1.08
8	G. J., - -	5	750	6	Oct., 1901,	15.6	17.8	16.5	4.5	5.1	4.9	.78	.85	.81	18.3	19.8	19.1	4.9	5.6	5.2	.94	1.04	.98
11	G. J., - -	4	650	1	Sept., 1901,	13.4	18.0	17.1	5.2	5.5	5.3	.70	.99	.91	16.2	18.6	17.3	5.0	5.7	5.5	.88	1.06	.96
	Average, -	—	**725**	—	—	—	—	**17.9**	—	—	**4.9**	—	—	**.88**	—	—	**19.0**	—	—	**5.3**	—	—	**1.01**
	Group D.																						
9	G. J., - -	6	**750**	1	Oct., 1901,	25.0	27.0	**25.9**	4.3	4.8	**4.6**	1.09	1.27	**1.19**	24.2	27.1	**25.8**	4.9	5.7	**5.4**	1.26	1.49	**1.38**
	Group E.																						
1	G. J., - -	7	**800**	1	—	30.2	34.6	**32.1**	4.0	4.8	**4.3**	1.21	1.66	**1.38**	32.2	35.3	**33.7**	4.2	5.0	**4.6**	1.39	1.73	**1.54**
	Herd Average,	—	**725**	—	—	—	—	**17.4**	—	—	**4.9**	—	—	**.84**	—	—	**18.0**	—	—	**5.3**	—	—	**.94**

AVERAGE DAILY RATION PER COW. HERD U.

Test No. 60. Timothy hay 5.7 lbs., mixed hay 7.1 lbs., corn stover 5.7 lbs., corn and cob meal 5 lbs., wheat bran 1.3 lbs., cotton seed meal 1.7 lbs.

Test No. 62. Basal: Mixed hay 10.5 lbs., corn stover 5.5 lbs., and 9 lbs. of grain feed mixed as follows: Corn and cob meal 300 lbs., wheat bran 400 lbs., cotton seed meal 200 lbs. Supplemental protein mixture: Group B, 1 lb., Group C, 2 lbs., Group D, 3 lbs, and Group E, 4 lbs., of grain feeds mixed as follows: Wheat bran 75 lbs., cotton seed meal 100 lbs, cream gluten meal 125 lbs.

Table 47.

Average weight of food and digestible nutrients fed per cow per day with fuel value and cost in dairy herd tests Nos. 60 and 62.

[Average weight of herd 725 lbs.]

Kind of Food.	Amount fed per day.	Digestible Nutrients and Fuel Value.						Nutritive ratio.	Cost.	Value of obt'nble manure.	Net cost.
		Protein.	Fat.	Carbohydrates.			Fuel Value.*				
				Nitrogen-free extract.	Fiber.	Total.					
First Test No. 60.	Lbs.	Lbs.	Lbs	Lbs.	Lbs.	Lbs.	Cal.	1:	Cts.	Cts.	Cts.
Whole Herd.											
Concentrated food, -	8.0	1.13	.39	3.75	.09	3.84	10890	4.2	7.3	3.1	4.2
Coarse food, - -	18.5	.64	.29	5.39	3.31	8.70	18590	14.6	11.3	3.7	7.6
Total food, -	**26.5**	**1.77**	**.68**	**9.14**	**3.40**	**12.54**	**29480**	**8.0**	**18.6**	**6.8**	**11.8**
Second Test No. 62.											
Group A.											
Concentrated food, -	9.0	1.42	.41	3.57	.14	3.71	11270	3.3	9.0	4.2	4.8
Coarse food, - -	16.0	.60	.23	4.74	2.80	7.54	16110	13.4	9.1	3.2	5.9
Total food, -	**25.0**	**2.02**	**.64**	**8.31**	**2.94**	**11.25**	**27380**	**6.3**	**18.1**	**7.4**	**10.7**
Group B.											
Concentrated food, -	10.0	1.69	.48	3.90	.15	4.05	12700	3.0	10.2	4.9	5.3
Coarse food, - -	16.0	.60	.23	4.74	2.80	7.54	16110	13.4	9.1	3.2	5.9
Total food, -	**26.0**	**2.29**	**.71**	**8.64**	**2.95**	**11.59**	**28810**	**5.8**	**19.3**	**8.1**	**11.2**
Group C.											
Concentrated food, -	11.0	1.96	.55	4.23	.17	4.40	14150	2.9	11.4	5.6	5.8
Coarse food, - -	16.0	.60	.23	4.74	2.80	7.54	16110	13.4	9.1	3.2	5.9
Total food, -	**27.0**	**2.56**	**.78**	**8.97**	**2.97**	**11.94**	**30260**	**5.3**	**20.5**	**8.8**	**11.7**
Group D.											
Concentrated food, -	12.0	2.24	.63	4.56	.18	4.74	15640	2.8	12.6	6.3	6.3
Coarse food, - -	16.0	.60	.23	4.74	2.80	7.54	16110	13.4	9.1	3.2	5.9
Total food, -	**28.0**	**2.84**	**.86**	**9.30**	**2.98**	**12.28**	**31750**	**5.0**	**21.7**	**9.5**	**12.2**
Group E.											
Concentrated food, -	13.0	2.51	.70	4.89	.19	5.08	17070	2.7	13.8	7.0	6.8
Coarse food, - -	16.0	.60	.23	4.74	2.80	7.54	16110	13.4	9.1	3.2	5.9
Total food, -	**29.0**	**3.11**	**.93**	**9.63**	**2.99**	**12.62**	**33180**	**4.7**	**22.9**	**10.2**	**12.7**

* See foot note p. 84.

TABLE 48.

Statistics of herd V during tests Nos. 63 and 65.

Ref. No.	Cows. Group and Breed.	Age.	Weight.	Mos. since last calf.	Due.	Test No. 63, Feb. 4 to 16, 1901. Daily Milk Flow. Min.	Max.	Avg.	Daily Pctg. Fat. Min.	Max.	Avg.	Daily Yield of Fat. Min.	Max.	Avg.	Test No. 65, Mar. 4 to 16, 1901. Daily Milk Flow. Min.	Max.	Avg.	Daily Pctg. Fat. Min.	Max.	Avg.	Daily Yield of Fat. Min.	Max.	Avg.
	Group A.	Yrs	Lbs	Mo		Lbs	Lbs	Lbs	%	%	%	Lbs	Lbs	Lbs	Lbs	Lbs	Lbs	%	%	%	Lbs	Lbs	Lbs
10	G. J., - - - -	12	800	7	May, 1901, - -	10.6	12.7	11.4	4.7	5.1	4.9	.51	.62	.56	11.6	13.2	12 3	4.7	5.2	5.0	.55	.66	.61
16	G. J., - - - -	15	750	5	Aug., 1901, - -	9.1	10.8	9.9	5.2	5.8	5.6	.50	.63	.55	8.3	10.6	9.2	4.9	6.0	5.5	.46	.61	.50
17	G. J., - - - -	5	750	6	Aug., 1901, - -	10.2	12.9	11.3	4.8	5.6	5.3	.49	.66	.60	9.3	11.4	10.3	5.0	5.8	5.5	.50	.65	.58
18	G. J., - - - -	5	750	5	May, 1901, - -	12.3	13.9	13.2	4.2	4.6	4.4	.53	.61	.58	10.4	11.3	10.9	4.7	5.4	5.0	.50	.60	.55
	Average, - -	—	760	—		—	—	11.5	—	—	5.1	—	—	.57	—	—	10.7	—	—	5.3	—	—	.56
	Group B.																						
3	G. H., - - -	4	850	6	May, 1901, - -	12.0	14.2	13.0	4.9	6.2	5.5	.61	.77	.71	11.2	13.2	12.0	5.4	6.0	5.8	.60	.78	.70
9	G. H., - - -	9	1000	4	—	17.6	23.8	20.0	3.9	4.8	4.3	.72	1.05	.86	18.8	24.0	20.7	4.0	4.5	4.3	.80	1.08	.89
12	G. J., - - -	9	800	5	Sept., 1901, - -	19.3	22.8	20.9	3.9	4.5	4.2	.81	.95	.90	19.6	22.4	21.1	4.0	4.5	4.3	.82	.99	.91
13	G. H., - - -	8	800	5	Aug., 1901, - -	15.0	16.7	15.8	4.2	4.7	4.6	.70	.77	.72	15.2	17.6	16.4	4.6	5.0	4.8	.71	.84	.79
14	G. J., - - -	5	750	4	July, 1901, - -	12.6	14.8	13.9	5.6	6.0	5.7	.72	.86	.80	13.5	15.0	14.3	5.3	6.1	5.8	.76	.89	.83
	Average, - -	—	840	—		—	—	16.7	—	—	4.9	—	—	.80	—	—	16.9	—	—	5.0	—	—	.82
	Group C.																						
2	G. J., - - -	7	750	5	Aug., 1901, - -	19.2	22.7	20.9	4.5	5.1	4.8	.88	1.11	1.00	20.6	24.5	22.5	4.8	5.2	5.0	1.02	1.23	1.12
8	G. H., - - -	8	1000	4	—	23.5	26.4	25.1	3.4	4.3	3.6	.82	1.13	.91	23.0	26.2	24.1	3.2	3.8	3.5	.77	.88	.83
15	G. J., - - -	8	750	5	—	18.6	21.2	19.8	4.3	4.8	4.6	.81	.98	.91	20.3	21.7	21.1	4.5	5.3	4.9	.98	1.11	1.03
	Average, - -	—	830	—		—	—	21.9	—	—	4.3	—	—	.94	—	—	22.6	—	—	4.5	—	—	.99
	Group D.																						
1	G. J., - - -	5	650	1	Nov., 1901, - -	23.6	28.8	26.6	4.2	5.6	4.8	1.08	1.55	1.28	22.4	25.0	23.7	4.7	5.7	5.2	1.08	1.43	1.22
5	G. J., - - -	6	750	1	—	23.6	28.1	25.8	4.0	4.6	4.3	.94	1.19	1.10	22.9	25.7	24.1	4.5	5.3	4.7	1.07	1.23	1.13
6	G. J., - - -	10	1000	1	Nov., 1901, - -	30.4	33.6	32.1	3.9	4.6	4.2	1.23	1.46	1.35	28.8	35.0	32.1	3.9	4.9	4.3	1.18	1.69	1.38
7	Devon, - -	8	750	1	Nov., 1901, - -	25.0	29.8	27.5	3.9	4.9	4.3	.98	1.48	1.18	26.6	30.0	28.2	4.0	4.6	4.2	1.06	1.35	1.19
11	G. J., - - -	6	800	2	Nov., 1901, - -	21.4	23.2	22.4	4.6	5.4	5.1	1.07	1.20	1.15	21.0	23.6	22.1	5.0	5.6	5.3	1.09	1.22	1.17
	Average, - -	—	790	—		—	—	26.9	—	—	4.5	—	—	1.21	—	—	26.0	—	—	4.7	—	—	1.22
	Herd Average,	—	800	—		—	—	19.4	—	—	4.7	—	—	.89	—	—	19.1	—	—	4.9	—	—	.91

AVERAGE DAILY RATION PER COW. HERD V.

Test No. 63. Corn stover 6.7 lbs., black grass 7.7 lbs., oat hay 4.6 lbs., mixed hay 2.4 lbs., and 11.8 lbs. of grain feeds mixed as follows: Wheat bran 200 lbs., corn and cob meal 150 lbs.

Test No. 65. Basal: Black grass 6 lbs., corn stover 5 lbs., oat hay 4 lbs., mixed hay 2 lbs., and 9 lbs. of grain feeds mixed as follows: Corn and cob meal 500 lbs., wheat bran 400 lbs., cotton seed meal 150 lbs., national gluten feed 125 lbs. Supplemental protein mixture: Group B, 1 lb., Group C, 2 lbs., Group D, 3 lbs., of grain feeds mixed as follows: Cotton seed meal 100 lbs., national gluten feed 100 lbs., corn and cob meal 100 lbs.

TABLE 49.

Average weight of food and digestible nutrients fed per cow per day with fuel value and cost in dairy herd tests Nos. 63 and 65.

[Average weight of herd 800 lbs.]

KIND OF FOOD.	Amount fed per day.	DIGESTIBLE NUTRIENTS AND FUEL VALUE.						Nutritive ratio.	Cost.	Value of obt'nble manure.	Net cost.
		Protein.	Fat.	CARBO-HYDRATES.			Fuel Value.*				
				Nitrogen-free extract.	Fiber.	Total.					
FIRST TEST NO. 63.	Lbs.	Lbs.	Lbs	Lbs.	Lbs.	Lbs.	Cal.	1:	Cts.	Cts.	Cts.
Whole Herd.											
Concentrated food, -	11.8	1.39	.35	5.56	.14	5.70	14660	4.7	10.6	4.5	6.1
Coarse food, - -	21.4	.80	.27	6.04	3.56	9.60	20480	12.8	11.1	4.2	6.9
Total food, -	**33.2**	**2.19**	**.62**	**11.60**	**3.70**	**15.30**	**35140**	**7.6**	**21.7**	**8.7**	**13.0**
SECOND TEST NO. 65.											
Group A.											
Concentrated food, -	9.5	1.40	.38	4.33	.13	4.46	12500	3.8	9.0	4.0	5.0
Coarse food, - -	17.0	.59	.22	4.67	2.63	7.30	15600	13.2	8.9	3.3	5.6
Total food, -	**26.5**	**1.99**	**.60**	**9.00**	**2.76**	**11.76**	**28100**	**6.6**	**17.9**	**7.3**	**10.6**
Group B.											
Concentrated food, -	10.5	1.63	.43	4.75	.15	4.90	13960	3.6	10.1	4.6	5.5
Coarse food, - -	17.0	.59	.22	4.67	2.63	7.30	15600	13.2	8.9	3.3	5.6
Total food, -	**27.5**	**2.22**	**.65**	**9.42**	**2.78**	**12.20**	**29560**	**6.2**	**19.0**	**7.9**	**11.1**
Group C.											
Concentrated food, -	11.5	1.86	.49	5.15	.17	5.32	15420	3.5	11.2	5.2	6.0
Coarse food, - -	17.0	.59	.22	4.67	2.63	7.30	15600	13.2	8.9	3.3	5.6
Total food, -	**28.5**	**2.45**	**.71**	**9.82**	**2.80**	**12.62**	**31020**	**5.8**	**20.1**	**8.5**	**11.6**
Group D.											
Concentrated food, -	12.5	2.10	.54	5.57	.19	5.76	16900	3.3	12.3	5.7	6.6
Coarse food, - -	17.0	.59	.22	4.67	2.63	7.30	15600	13.2	8.9	3.3	5.6
Total food, -	**29.5**	**2.69**	**.76**	**10.24**	**2.82**	**13.06**	**32500**	**5.5**	**21.2**	**9.0**	**12.2**

* See foot note p. 84.

Table 50.

Statistics of herd W during tests Nos. 64 and 66.

Ref. No.	Cows. Group and Breed.	Age.	Weight.	Mos. since last c'lf.	Due.	Test No. 64, Feb. 18 to Mar. 2, 1901. Daily Milk Flow. Min.	Max.	Avg.	Daily Pctg. Fat. Min.	Max.	Avg.	Daily Yield of Fat. Min.	Max.	Avg.	Test No. 66, Mar. 18 to 30, 1901. Daily Milk Flow. Min.	Max.	Avg.	Daily Pctg. Fat. Min.	Max.	Avg.	Daily Yield of Fat. Min.	Max.	Avg.
	Group A.					Lbs	Lbs	Lbs	%	%	%	Lbs	Lbs	Lbs	Lbs	Lbs	Lbs	%	%	%	Lbs	Lbs	Lbs
2	G. G.,	12	850	5	Dec., 1901,	11.6	13.2	13.1	3.7	5.1	4.6	.43	.72	.60	11.2	13.5	12.1	4.7	5.0	4.9	.56	.66	.59
4	G. A.,	12	675	4	Dec., 1901,	13.9	15.9	14.8	4.3	5.0	4.7	.64	.72	.69	12.6	13.9	13.4	4.7	5.0	4.9	.61	.69	.66
11	Common,	12	950	1	—	11.4	12.9	12.4	4.1	5.2	4.9	.53	.64	.61	11.7	16.5	12.6	4.8	5.5	5.3	.56	.82	.67
12	G. S.,	13	950	5	Dec., 1901,	12.7	16.4	15.1	4.0	5.0	4.6	.63	.77	.70	14.8	16.4	15.5	4.6	5.0	4.8	.68	.79	.75
22	G. S.,	4	1000	—	Nov., 1901,	14.6	16.7	15.4	4.4	4.8	4.5	.65	.75	.70	13.6	15.5	14.7	4.4	4.9	4.7	.63	.77	.69
27	Common,	5	800	5	Dec., 1901,	14.4	18.6	16.2	4.1	4.6	4.3	.63	.80	.70	15.8	17.0	16.3	4.1	4.4	4.3	.65	.75	.71
29	G. S.,	5	975	3	—	11.8	15.2	14.2	4.6	5.5	5.0	.59	.81	.71	11.4	13.4	12.2	5.0	5.6	5.3	.59	.70	.65
	Average,	—	**875**	—	—	—	—	**14.5**	—	—	**4.7**	—	—	**.67**	—	—	**13.8**	—	—	**4.9**	—	—	**.67**
	Group B.																						
1	Common,	12	850	2	—	15.4	17.6	16.6	4.3	5.1	4.6	.66	.86	.77	14.4	16.7	15.2	4.0	5.1	4.3	.59	.79	.65
6	G. S.,	5	1000	5	Dec., 1901,	18.2	21.0	19.2	4.0	4.8	4.5	.82	.95	.87	17.2	19.3	18.3	4.4	4.8	4.7	.77	.93	.85
7	G. S.,	5	1075	3	—	17.0	19.3	18.1	4.1	5.0	4.6	.71	.93	.83	16.3	18.3	17.1	4.8	5.2	5.0	.82	.89	.85
10	Common,	5	950	1	—	19.1	23.2	21.1	3.7	4.8	4.0	.76	.97	.84	18.7	22.7	20.0	3.9	4.4	4.2	.75	1.00	.84
15	Common,	12	900	—	Dec., 1901,	16.6	19.4	18.0	4.6	5.1	4.9	.81	.93	.88	14.2	15.4	14.8	4.9	5.3	5.2	.74	.78	.76
16	G. S.,	4	1000	3	Jan., 1902,	15.4	18.5	16.9	4.4	5.6	4.8	.69	.87	.81	16.0	18.6	17.6	4.6	4.8	4.7	.74	.86	.82
18	G. J.,	7	750	1	—	19.0	21.6	20.3	4.0	4.8	4.3	.80	.97	.88	17.0	18.8	18.0	4.4	4.6	4.5	.76	.85	.81
23	G. J.,	10	800	6	Dec., 1901,	16.2	18.2	17.5	4.8	5.3	5.0	.78	1.02	.87	15.8	18.4	16.8	5.0	5.4	5.3	.83	.96	.89
28	G. S.,	4	975	3	—	16.0	18.6	17.3	4.3	4.9	4.7	.73	.89	.81	15.7	17.1	16.3	4.8	5.6	5.1	.79	.98	.84
30	G. S.,	6	1000	—	—	16.6	19.6	18.3	4.3	5.0	4.7	.75	.96	.85	16.2	17.7	17.0	4.6	5.0	4.9	.74	.87	.82
	Average,	—	**925**	—	—	—	—	**18.3**	—	—	**4.6**	—	—	**.84**	—	—	**17.1**	—	—	**4.8**	—	—	**.81**
	Group C.																						
3	Common,	4	850	1	—	24.0	26.2	25.2	4.0	4.7	4.5	1.04	1.18	1.12	21.3	24.1	23.0	4.5	5.0	4.8	1.01	1.16	1.10
5	G. J.,	12	675	1	—	19.6	23.1	21.6	4.8	5.4	5.1	.96	1.24	1.10	16.7	19.4	18.4	5.4	5.7	5.6	.94	1.08	1.02
8	G. S.,	5	1000	1	—	22.6	27.5	25.2	3.6	4.7	4.1	.94	1.14	1.02	23.6	25.9	24.6	3.8	4.0	3.9	.90	1.00	.96
9	G. S.,	5	1025	1	—	29.0	31.2	30.0	2.9	4.0	3.5	.87	1.22	1.07	22.0	28.0	25.4	3.9	4.2	4.1	.90	1.15	1.04
13	G. J.,	7	900	—	—	21.4	23.5	22.7	4.2	5.0	4.6	.98	1.11	1.04	21.2	23.4	22.5	4.8	5.1	4.9	1.03	1.17	1.10
14	G. J.,	5	800	2	—	15.9	21.2	19.0	4.1	5.4	4.9	.81	1.03	.92	14.3	17.8	16.1	4.9	5.5	5.2	.76	.93	.84
17	G. J.,	14	900	4	Jan., 1902,	18.8	22.9	21.2	4.3	5.2	4.7	.87	1.19	.99	18.0	20.8	19.4	4.4	5.2	4.9	.82	1.06	.95
19	G. J.,	12	750	1	—	26.8	31.3	28.6	3.5	4.1	3.8	1.00	1.28	1.10	23.8	27.1	25.2	3.8	4.1	3.9	.92	1.05	.99
20	G. J.,	7	950	3	—	19.2	24.3	22.6	3.7	4.9	4.3	.77	1.08	.98	19.9	23.1	21.2	4.8	5.1	4.9	1.00	1.14	1.03
21	G. J.,	3	900	3	—	16.8	20.0	18.6	4.7	5.5	5.1	.84	1.00	.94	17.4	18.8	18.0	5.4	5.7	5.6	.96	1.05	1.00
24	G. J.,	4	800	—	—	21.7	24.2	23.0	3.4	4.8	4.3	.76	1.14	1.00	18.9	22.7	21.2	4.4	5.4	4.7	.92	1.07	1.00
25	G. S.,	4	900	1	—	20.4	23.7	22.6	4.2	4.7	4.5	.94	1.08	1.00	20.9	22.3	21.7	4.4	4.8	4.6	.92	1.03	1.00
26	G. S.,	12	850	1	—	20.6	25.2	22.3	4.0	4.5	4.3	.85	1.13	.96	18.9	20.5	19.6	4.2	4.8	4.6	.79	.98	.90
	Average,	—	**875**	—		—	—	**23.3**	—	—	**4.4**	—	—	**1.02**	—	—	**21.3**	—	—	**4.7**	—	—	**.99**
	Herd Average,	—	**900**	—		—	—	**19.6**	—	—	**4.5**	—	—	**.88**	—	—	**18.1**	—	—	**4.8**	—	—	**.86**

AVERAGE DAILY RATION PER COW. HERD W.

Test No. 64. Corn and soy bean silage 22.5 lbs., mixed hay 11.3 lbs., and 8.2 lbs. of grain feeds mixed as follows: Wheat middlings 300 lbs., hominy chop 100 lbs., cotton seed meal 150 lbs.

Test No. 66. For all the cows alike, corn and soy bean silage 22.5 lbs., and mixed hay 10 lbs., and for the cows in Group A, 7.5 lbs., those in Group B, 8.5 lbs., and those in Group C, 9.5 lbs. of grain feeds mixed as follows: Wheat bran 400 lbs., cotton seed meal 200 lbs., Chicago gluten meal 100 lbs., hominy chop 100 lbs.

Table 51.

Average weight of food and digestible nutrients fed per cow per day with fuel value and cost in dairy herd tests Nos. 64 and 66.

[Average weight of herd 900 lbs.]

Kind of Food.	Amount fed per day.	Digestible Nutrients and Fuel Value.						Nutritive ratio.	Cost.	Value of obt'nble manure.	Net cost.
		Protein.	Fat.	Carbohydrates.			Fuel Value.*				
				Nitrogen-free extract.	Fiber.	Total.					
First Test No. 64.	Lbs.	Lbs.	Lbs	Lbs.	Lbs.	Lbs.	Cal.	1:	Cts.	Cts.	Cts.
Whole Herd.											
Concentrated food, -	8.2	1.57	.43	3.70	.12	3.82	11830	3.1	8.8	4.3	4.5
Coarse food, - -	33.8	.83	.38	5.79	2.82	8.61	19160	11.4	11.3	4.0	7.3
Total food, -	**42.0**	**2.40**	**.81**	**9.49**	**2.94**	**12.43**	**30990**	**5.9**	**20.1**	**8.3**	**11.8**
Second Test No. 66.											
Group A.											
Concentrated food, -	7.5	1.61	.40	2.75	.12	2.87	10020	2.3	8.3	4.6	3.7
Coarse food, - -	32.5	.87	.33	5.69	2.42	8.11	18100	10.2	10.4	3.7	6.7
Total food, -	**40.0**	**2.48**	**.73**	**8.44**	**2.54**	**10.98**	**28120**	**5.1**	**18.7**	**8.3**	**10.4**
Group B.											
Concentrated food, -	8.5	1.83	.45	3.11	.14	3.25	11340	2.3	9.4	5.1	4.3
Coarse food, - -	32.5	.87	.33	5.69	2.42	8.11	18100	10.2	10.4	3.7	6.7
Total food, -	**41.0**	**2.70**	**.78**	**8.80**	**2.56**	**11.36**	**29440**	**4.9**	**19.8**	**8.8**	**11.0**
Group C.											
Concentrated food, -	9.5	2.04	.51	3.48	.15	3.63	12700	2.3	10.5	5.7	4.8
Coarse food, - -	32.5	.87	.33	5.69	2.42	8.11	18100	10.2	10.4	3.7	6.7
Total food, -	**42.0**	**2.91**	**.84**	**9.17**	**2.57**	**11.74**	**30800**	**4.7**	**20.9**	**9.4**	**11.5**

* See foot note p. 84.

DISCUSSION OF THE TESTS.

Herd T. Tests Nos. 59 and 61.—This experiment was made with a herd of thirteen cows, the animals being the same in both tests. The cows were all grade Jerseys and were estimated to weigh from 700 to 850 pounds. Most of the cows had calved within six months prior to the first test, and none were due to calve within three months of the close of the second test. The herd was well stabled, the temperature being quite uniform irrespective of the weather. The coarse fodder used consisted of corn stover, finely cut, and oat hay of good quality.

The first test began December 11 and continued twelve days. In this test the average daily ration was composed of about 10 pounds of oat hay and 8 pounds of corn stover, and about 8.5 pounds of mixed grains consisting of wheat bran, corn meal and oat feed, with a very little cotton seed meal. The ration was estimated to contain 1.75 pounds of digestible protein and was quite a wide one, having a ratio of 1:7.6.

There was an interval of sixteen days between the tests. The second test began January 8 and continued twelve days. The same kinds of coarse fodders were used in this test as in the first, although the amount of oat hay was slightly reduced. The grain feed of the basal ration consisted of 8.0 pounds daily of a mixture of 150 pounds of Quaker dairy feed, 300 pounds of wheat bran, 200 pounds of corn meal, 75 pounds of cotton seed meal and 125 pounds of Chicago gluten meal, and furnished about 2.0 pounds of digestible protein per day. The protein mixture for the supplemental ration consisted of equal parts by weight of cotton seed and Chicago gluten meals and Quaker dairy feed. There were two groups of cows which received the protein mixture in addition to the basal grain feed. In one group (B) there were four cows which received one pound each, and in another group (C) there were five cows which received two pounds each of the protein mixture. There was estimated to be .25 of a pound of digestible protein in each pound of the mixture, and the amount of protein fed was increased one pound for every .15 of a pound of butter fat produced above .65 of a pound. There were two cows, however, whose yields of butter fat in the first test indicated that they should have received three pounds of the protein mixture if

this plan of feeding had been strictly followed. As the cows had not been accustomed to heavy grain feeding it was thought best not to increase above two pounds of this mixture, making a total of 2.13 pounds of digestible protein daily.

TABLE 52.

Summarized results with herd T. Tests Nos. 59 and 61.

[First test Dec. 11-22, 1900. Second test Jan. 8-19, 1901.]

	Digestible Nutrients and Fuel Value.					Av. Daily Yield.		Cost of ration.	Cost 100 lbs. milk.	Cost 1 lb. butter.
	Protein.	Fat.	Carbo-hydrates.	Fuel Value.*	Nutritive ratio	Milk.	Butter.			
Group A, 4 cows:	Lbs.	Lbs	Lbs.	Cal.	1:	Lbs.	Lbs.	Cts.	$	Cts.
1st test, - - -	1.75	.61	11.90	27960	7.6	10.9	.71	17.0	1.56	23.9
2d test, - - -	1.62	.55	9.71	23390	6.8	11.4	.77	15.8	1.39	20.5
Group B, 4 cows:										
1st test, - - -	1.75	.61	11.90	27960	7.6	12.4	.79	17.0	1.37	21.5
2d test, - - -	1.88	.61	10.05	24760	6.1	13.6	.89	17.0	1.25	19.1
Group C, 5 cows:										
1st test, - - -	1.75	.61	11.90	27960	7.6	17.9	1.07	17.0	.95	15.9
2d test, - - -	2.13	.66	10.40	26090	5.6	18.3	1.13	18.2	.99	16.1
Average of herd, 13 cows:										
1st test, - - -	1.75	.61	11.90	27960	7.6	14.1	.87	17.0	1.21	19.5
2d test, - - -	1.90	.61	10.08	24860	6.0	14.7	.94	17.1	1.16	18.2

Comparing the data obtained in the two tests on herd T, it will be seen that in the case of the first test the average cost of the ration for the entire herd was 17.0 cents and in the second test 17.1 cents; while the average daily yields were 14.1 pounds of milk and .87 pound of butter in the first test, and 14.7 pounds of milk and .94 pound of butter in the second test. The average food cost of producing 100 pounds of milk was 5.0 cents less, and of one pound of butter 1.3 cents less in the second test than in the first. The feeding of different amounts of protein to different cows according to the yields of butter fat is seen in this experiment to have been more economical than feeding a uniform ration, rather low in protein, for the entire herd.

Herd U. Tests Nos. 60 and 62.—Thirteen animals were included in each of the tests of this experiment, twelve being grade Jerseys and one a grade Holstein. The average estimated weight of the cows was 725 pounds. Most of the cows

* See foot note p. 84.

had calved within six months previous to the first test, and none were due to calve until four months or more after the close of the second test. The herd was well stabled and was watered in a protected yard, where the animals were allowed to exercise in mild weather. The coarse fodder used was produced on the farm, and consisted of hay of good quality and corn stover. The grain mixture fed in the first test consisted largely of corn which was grown on the farm.

The first test on this herd began December 26 and continued eleven days. In this test all the cows were supposed to have essentially a uniform ration, but the amount of grain fed to each varied somewhat, causing the ration to differ slightly for the different cows. In this test the average daily coarse fodders consisted of about 7 pounds of hay of mixed grasses, 6 pounds of timothy hay and 5.5 pounds of corn stover. The average daily grain feed consisted of 5 pounds of corn and cob meal, about one pound of wheat bran and a little less than 2 pounds of cotton seed meal. This ration was estimated to contain 1.77 pounds of digestible protein, and to have a nutritive ratio of 1:8.0.

There was an interval of sixteen days between tests. The second began January 21 and continued twelve days. Owing to a lack of the cheaper coarse fodders, especially corn stover, more hay was fed in the second test than was thought to be desirable. The coarse fodders consisted of about 10 pounds of hay of mixed grasses and 5.5 pounds of corn stover. The basal grain ration consisted of about 9 pounds daily of a mixture of 300 pounds of corn and cob meal, 400 pounds of wheat bran and 200 pounds of cotton seed meal, and furnished about 2 pounds of digestible protein daily. The protein grain mixture was made up of 100 pounds of cotton seed meal, 125 pounds of Chicago gluten meal and 75 pounds of wheat bran. It was estimated to furnish .27 of a pound of digestible protein for each pound of the mixture. In this test four groups of cows were fed the protein grain mixture. In group B there were five cows which were fed one pound each; in group C there were four cows which received two pounds each, and one cow in each of groups D and E received three and four pounds of the protein mixture respectively.

TABLE 53.

Summarized results with herd U. Tests Nos. 60 and 62.

[First test Dec. 26, 1900–Jan. 5, 1901. Second test Jan. 21–Feb. 2, 1901.]

	Digestible Nutrients and Fuel Value.					Av. Daily Yield.				
	Protein.	Fat.	Carbo-hydrates.	Fuel Value.*	Nutritive ratio	Milk.	Butter.	Cost of ration.	Cost 100 lbs. milk.	Cost 1 lb. butter.
	Lbs.	Lbs	Lbs.	Cal.	1:	Lbs.	Lbs.	Cts.	$	Cts.
Group A, 2 cows:										
1st test, - - -	1.77	.68	12.54	29480	8.0	11.6	.64	18.6	1.60	29.1
2d test, - - -	2.02	.64	11.25	27380	6.3	13.2	.79	18.1	1.37	22.9
Group B, 5 cows:										
1st test, - - -	1.77	.68	12.54	29480	8.0	14.3	.84	18.6	1.30	22.1
2d test, - - -	2.29	.71	11.59	28810	5.8	14.4	.93	19.3	1.34	20.8
Group C, 4 cows:										
1st test, - - -	1.77	.68	12.54	29480	8.0	17.9	1.03	18.6	1.04	18.1
2d test, - - -	2.56	.78	11.94	30260	5.3	19.0	1.18	20.5	1.08	17.4
Group D, 1 cow:										
1st test, - - -	1.77	.68	12.54	29480	8.0	25.9	1.39	18.6	.72	13.4
2d test, - - -	2.84	.86	12.28	31750	5.0	25.8	1.61	21.7	.84	13.5
Group E, 1 cow:										
1st test, - - -	1.77	.68	12.54	29480	8.0	32.1	1.61	18.6	.58	11.6
2d test, - - -	3.11	.93	12.62	33180	4.7	33.7	1.80	22.9	.68	12.7
Average of herd, 13 cows:										
1st test, - - -	**1.77**	**.68**	**12.54**	**29480**	**8.0**	**17.4**	**.98**	**18.6**	**1.07**	**19.0**
2d test, - - -	**2.44**	**.75**	**11.78**	**29610**	**5.5**	**18.0**	**1.10**	**19.9**	**1.10**	**18.1**

Table 53 gives the results obtained in the separate tests with the different groups of cows. The average cost of the ration used in the second test was 1.3 cents more than in the first test. The average yield of milk was .6 pound more and of butter .12 pound more in the second test than in the first. The cost of producing 100 pounds of milk was 3.0 cents more, while the cost of one pound of butter was nearly one cent less in the second than in the first test. When the average food cost of one pound of butter in the second test is compared with the average food cost of the same amount of butter in the first test, it will be noticed that the rations providing over 2.56 pounds of protein were less economical than the average ration in the first test, which provided only 1.77 pounds of protein. Although the average milk yield was slightly more in the second test than in the first, the cost of milk was not reduced; while in the case of the butter the yield was greater in the

* See foot note p. 84.

second test and the cost was reduced. This was due to the fact that the milk in the second test contained a higher average percentage of butter fat.

Herd V. Tests Nos. 63 and 65.—The total number of cows in each of the tests with this herd was seventeen, twelve of which were grade Jerseys, four grade Holsteins and one a Devon. The cows varied in estimated weight from 750 to 1,000 pounds, the average being placed at 800 pounds. Nearly all the cows had calved within six months previous to the first test, and none were due to calve within two months after the close of the second test. The cows were fed a large amount of coarse fodder, consisting of black grass hay, mixed hay and corn stover, and in addition quite a large proportion of corn grown on the farm.

The first test began February 4 and lasted twelve days. During this test a large amount of hay and corn stover was fed, the average daily allowance per cow being 21.4 pounds. The grain mixture consisted of 200 pounds of wheat feed and about 150 pounds of corn and cob meal, which was fed at the rate of about 12.0 pounds per cow each day. The average ration fed in the first test was estimated to contain 2.19 pounds of digestible protein and to have a nutritive ratio of 1:7.6.

After an interval of sixteen days the second test was begun, on March 4, and continued the usual period of time. The coarse fodder used daily in this test consisted of a total of 17 pounds of oat hay, black grass hay and corn stover. The basal grain mixture was made up of 500 pounds of corn and cob meal, 400 pounds of wheat bran, 150 pounds of cotton seed meal and 125 pounds of national gluten feed, and was fed at the rate of 9.5 pounds per day. The protein mixture consisted of equal parts of cotton seed meal, national gluten feed and corn and cob meal. The basal grain mixture with the coarse fodder gave a ration containing approximately 2 pounds of digestible protein per day, while the protein mixture furnished approximately .2 of a pound of digestible protein for each pound of the mixture.

The cows were divided into four groups in the second test, one of which (A) containing four cows received the basal ration only, another (B) containing five cows received 1 pound of the

protein mixture in addition to the basal ration, another (C) containing three cows received 2 pounds extra, and another (D) containing five cows received 3 pounds extra.

It will be noted from the above that the rate at which the protein was increased, for the more productive cows, was reduced in this from what it was in the last two experiments. The increase in the protein fed, however, was made on the basis of a smaller increase in the yields of butter fat, as shown in the tabulation on page 83.

TABLE 54.

Summarized results with herd V. Tests Nos. 63 and 65.

[First test Feb. 4-16, 1901. Second test Mar. 4-16, 1901.]

	Digestible Nutrients and Fuel Value.					Av. Daily Yield.				
	Protein.	Fat.	Carbo-hydrates.	Fuel Value.*	Nutritive ratio	Milk.	Butter.	Cost of ration.	Cost 100 lbs. milk.	Cost 1 lb. butter.
	Lbs.	Lbs	Lbs.	Cal.	1:	Lbs.	Lbs.	Cts.	$	Cts.
Group A, 4 cows:										
1st test, - - -	2.19	.62	15.30	35140	7.6	11.5	.67	21.7	1.88	32.4
2d test, - - -	1.99	.60	11.76	28100	6.6	10.7	.65	17.9	1.67	27.5
Group B, 5 cows:										
1st test, - - -	2.19	.62	15.30	35140	7.6	16.7	.93	21.7	1.30	23.3
2d test, - - -	2.22	.65	12.20	29560	6.2	16.9	.96	19.0	1.12	19.8
Group C, 3 cows:										
1st test, - - -	2.19	.62	15.30	35140	7.6	21.9	1.10	21.7	.99	19.7
2d test, - - -	2.45	.71	12.62	31020	5.8	22.6	1.16	20.1	.89	17.3
Group D, 5 cows:										
1st test, - - -	2.19	.62	15.30	35140	7.6	26.9	1.41	21.7	.81	15.4
2d test, - - -	2.69	.76	13.06	32500	5.5	26.0	1.42	21.2	.82	14.9
Average of herd, 17 cows:										
1st test, - - -	**2.19**	**.62**	**15.30**	**35140**	**7.6**	**19.4**	**1.04**	**21.7**	**1.12**	**20.9**
2d test, - - -	**2.34**	**.68**	**12.42**	**30320**	**6.0**	**19.1**	**1.06**	**19.6**	**1.03**	**18.5**

The results of this experiment are interesting because of the reduction in the cost of the ration, and in the cost of producing milk and butter in the second test as compared with the first. In every group the cost of producing 100 pounds of milk and one pound of butter was less in the second test. The milk and the butter yields were nearly alike in the two tests, which would tend to show that the saving must have been due to the cheaper ration in the second test. An excessive amount of

* See foot note p. 84.

coarse fodder was fed and the animals rejected quite a little of it. The grain feed was not an expensive one, as most of the corn was grown on the farm; yet a grain mixture with a little larger proportion of protein seemed to give better results. A considerable saving in the cost of producing milk and butter was made in this experiment when from 2.20 to 2.45 pounds of protein were fed, as compared with 2.19 pounds in the first test.

Herd W. Tests Nos. 64 and 66.—This was a large herd of about fifty cows, from which thirty were selected as suitable for the experiment. The cows were mainly grade Swiss and a few were grade Jerseys and natives. Most of them were medium sized, the average estimated weight being 900 pounds. All but one had calved within five months previous to the first test, and, as far as known, none were due to calve within five months of the close of the second test. The herd was kept in a high, well ventilated stable, and was allowed to exercise in a yard in pleasant weather.

The coarse fodder in the daily ration of the first test consisted of about 22 pounds of corn and soy bean silage and 11.3 pounds of a fair quality of hay. The grain ration was composed of about 8 pounds of a mixture of three parts, by weight, of flour middlings, one part of hominy chop and one and one-half parts of cotton seed meal. It was supposed that this ration would furnish about 2 pounds of digestible protein daily, but after samples were analyzed it was calculated to contain about 2.4 pounds of digestible protein daily. The large amount of protein in the ration was due, to a considerable degree, to the high percentage of protein contained in the corn and soy bean silage.

In the second test it was thought best to test the value of a larger amount of protein than 2.4 pounds, and to increase the protein according to the yields of butter fat, on the same plan as in the last experiment (Herd V). The hay used in the second test was reduced to an average of 10 pounds per day. The basal grain mixture consisted of four parts, by weight, of wheat bran, two parts of cotton seed meal and one part each of hominy chop and Chicago gluten meal. No second grain or protein mixture was used in this test, but the mixture named was fed to different groups at the rate of 7.5, 8.5 and 9.5

pounds per cow daily. In this way the protein was increased approximately .2 of a pound for the different groups according to the yields of butter fat. But the nutritive ratio was not decreased as rapidly by this method of feeding as in the cases where a protein grain mixture was used.

TABLE 55.

Summarized results with herd W. Tests Nos. 64 and 66.

[First test Feb. 18–Mar. 2, 1901. Second test Mar. 18–30, 1901.]

	Digestible Nutrients and Fuel Value.					Av. Daily Yield.				
	Protein.	Fat.	Carbo-hydrates.	Fuel Value.*	Nutritive ratio	Milk.	Butter.	Cost of ration.	Cost 100 lbs. milk.	Cost 1 lb. butter.
	Lbs.	Lbs	Lbs.	Cal.	1:	Lbs.	Lbs.	Cts.	$	Cts.
Group A, 7 cows:										
1st test, - - -	2.40	.81	12.43	30990	5.9	14.5	.78	20.1	1.39	25.8
2d test, - - -	2.48	.73	10.98	28120	5.1	13.8	.78	18.7	1.36	24.0
Group B, 10 cows:										
1st test, - - -	2.40	.81	12.43	30990	5.9	18.3	.98	20.1	1.10	20.5
2d test, - - -	2.70	.78	11.36	29440	4.9	17.1	.95	19.8	1.16	20.8
Group C, 13 cows:										
1st test, - - -	2.40	.81	12.43	30990	5.9	23.3	1.19	20.1	.86	16.9
2d test, - - -	2.91	.84	11.74	30800	4.7	21.3	1.16	20.9	.98	18.0
Average of herd, 30 cows:										
1st test, - - -	**2.40**	**.81**	**12.43**	**30990**	**5.9**	**19.6**	**1.03**	**20.1**	**1.03**	**19.5**
2d test, - - -	**2.74**	**.79**	**11.44**	**29710**	**4.8**	**18.1**	**1.00**	**20.0**	**1.10**	**20.0**

The results of this test show that when the ration contained over 2.5 pounds of protein per day the food cost of milk and butter was relatively greater than when 2.4 pounds of protein were used. This would seem to indicate that at the prices existing during the period covered by these tests the limit of protein feeding for the most profitable results is about 2.5 pounds daily.

SUMMARY.

Four herds of cows were studied during the winter of 1900–1901. Two tests were made with each herd, covering periods of twelve days each in all except one test, which lasted eleven days.

In the first test the entire herd was fed the ration in use by the dairyman, which usually was nearly the same for all cows of the herd. The amount of protein in the ration varied for the different herds from 1.75 to 2.40 pounds per cow per day.

* See foot note p. 84.

In the second test the ration was varied according to the yields of butter fat produced in the first test. Two grain mixtures were used in this test; the first was included with the coarse fodders in what was called a basal ration, which was planned to contain about the same amount of protein as the average ration used in the first test; the second grain mixture, called a protein mixture, was chiefly made up of concentrated nitrogenous grain feeds, combined in such proportions as to furnish, in the different cases, between .2 and .3 of a pound of protein for each pound of the mixture. The plan of feeding in this test was to use the basal ration uniformly for all cows in the test, and to add to this certain quantities of the protein mixture, varying for the different cows according to the average daily amount of butter fat they had produced in the first test.

The results of the two tests with each of the four herds are summarized in the following table; the figures in the table are averages for the total number of cows in each test.

TABLE 56.

Summary of daily rations fed, and daily milk and butter yield.

Herd.	Average weight of cows.	Number of test.	Daily Ration per Head					Average Daily		Cost of Food to Produce			
										100 lbs. Milk.		1 lb. Butter.	
			Digestible protein.	Fuel value of digestible nutrients.	Nutritive ratio.	Total cost.	Net cost.*	Milk flow.	Yield of butter.†	Total cost.	Net cost.	Total cost.	Net cost.
	Lbs.		Lbs.	Cal.	1:	Cts.	Cts.	Lbs.	Lbs.	$	Ct	Ct.	Ct
T, 1st test,	750	59	1.75	27960	7.6	17.0	10.3	14.1	.87	1.21	73	19.5	12
T, 2d test,	750	61	1.90	24860	6.0	17.1	10.1	14.7	.94	1.16	69	18.2	11
U, 1st test,	725	60	1.77	29480	8.0	18.6	11.8	17.4	.98	1.07	68	19.0	12
U, 2d test,	725	62	2.44	29610	5.5	19.9	11.5	18.0	1.10	1.10	64	18.1	10
V, 1st test,	800	63	2.19	35140	7.6	21.7	13.0	19.4	1.04	1.12	67	20.9	13
V, 2d test,	800	65	2.34	30320	6.0	19.6	11.4	19.1	1.06	1.03	60	18.5	11
W, 1st test,	900	64	2.40	30990	5.9	20.1	11.8	19.6	1.03	1.03	60	19.5	11
W, 2d test,	900	66	2.74	29710	4.8	20.0	11.1	18.1	1.00	1.10	61	20.0	11

The cost of the average ration was less in the second test for one herd, practically the same for two herds, and was more in the second test for one herd. The average food cost of producing 100

* Total cost less value of obtainable manure.

† On the assumption that the amount of butter that can be made is equivalent to seven-sixths of the amount of butter fat produced.

pounds of milk was less in the second test for two herds and was more for the other two herds. The average food cost of one pound of butter was less in the cases of three herds and more in the case of one herd in the second tests.

When the food cost of producing milk and butter is compared by groups of cows fed different amounts of protein in the first and second tests, it appears that the cost of producing one pound of butter was less in nearly all groups in the second test than in the first, when the amount of protein in the second test was not more than about 2.6 pounds per day. The gains in yields and profit in the second tests seem to be most marked when the results from the use of from 1.9 to 2.4 pounds of protein are compared with those from the use of smaller quantities.

The economy of feeding according to the yields of milk or butter fat depends much upon what yields are taken as a basis. In these experiments, where about 2 pounds of protein was used as a basal ration for a yield of .5 of a pound of butter fat daily, and the protein was increased from .20 to .27 of a pound for an increase of from .15 to .20 of a pound of butter fat, the food cost of production was generally less, until the protein reached about 2.6 pounds, than where uniform rations with smaller amounts of protein were used. The number of experiments is too small and the variations in the amounts of protein fed are too limited to be used as a basis for judging the amounts of protein needed for a given yield of butter fat; but the indications are that the amount of protein fed should be between 1.9 and 2.5 pounds, varying according to the productiveness of the cow.

EFFICIENCY OF A COVERED PAIL IN EXCLUDING FILTH AND BACTERIA FROM MILK.

BY W. A. STOCKING, JR.

Milk of good quality should contain certain proportions of protein, fats and carbohydrates, and should be free from all foreign matter and noxious organisms. Its chemical composition and its appearance, odor and taste should remain unchanged for a reasonable length of time, and it should reach the consumer in a clean, wholesome condition. Unfortunately the average milk, as obtained under ordinary conditions, while perhaps meeting all requirements as regards chemical composition, too often contains an appreciable amount of foreign matter, consisting of dust, dirt, excreta, skin, hair, etc., which during the milking fall into the pail from the air, the cow, and the hands and clothing of the milker. Not only is such contamination objectionable in itself, but the particles which fall into the milk commonly introduce various species of bacteria which, finding an excellent medium in which to grow, frequently give serious trouble to those who use the milk. Among the bacteria thus introduced into the milk may be those which produce very undesirable effects in the products of creameries, cheese factories, etc., those which cause milk under ordinary conditions to spoil rapidly, and even those which produce serious illness in persons who drink the milk. Having once gained access to the milk these noxious organisms are not easily destroyed by any means that will not at the same time materially affect the condition of the milk itself.

There is a rapidly growing demand for cleaner and more wholesome milk, both for direct consumption and for the production of butter, cheese and other milk products, and progressive dairymen are desirous of knowing how to meet this demand. The increasing interest and importance of this question led the Station to undertake the work described in this article.

Various methods of clarifying milk, such as straining, filtering, sedimentation, and the use of centrifugal machines, have been employed both in this country and in Europe. Some of these have been fairly successful in removing both dirt and bacteria, but none have proved entirely satisfactory. One important objection to such methods of handling milk, especially in the small dairy, is that they involve considerable time, and some of them additional machinery, and thus add to the cost of production.

It is much more important, however, to go further back than this, and to prevent the dirt from getting into the milk at all, because a good deal of it dissolves readily in the warm milk and therefore cannot be removed, and thus contaminates the milk with both filth and the bacteria of the dirt. It is necessary, therefore, to secure some means whereby the dirt may be originally excluded.

It has been found that if the stables are well cleaned and ventilated and exposed to sunlight, if the cows are kept well brushed and cleaned, if just before milking the parts of the cow immediately above and around the pail are washed, and if the milker is clean and wears clean clothes and uses sterile utensils, the quantities of dirt and bacteria which get into the milk are greatly reduced.

Devices for excluding the dirt have also been tried in this country and in Europe. One of the simplest and most practical of these is a milking pail with a cover for reducing the area of the surface exposed during the milking. In order to test the efficiency of such a pail for keeping out dirt that would fall into an open pail, the writer carried on a number of experiments during the winter of 1901-1902 at the Connecticut Agricultural College. In connection with these experiments a number of other observations were made, the whole investigation including:

1. The efficiency of the covered pail in excluding dirt from the milk.

2. The relation between the amount of dirt in the milk and the keeping property of the milk.

3. The relation between the amount of dirt in the milk and the germ content.

4. The relation of the germ content to the keeping property of the milk.

5. A comparison of the results obtained with a covered pail and by straining milk from an open pail immediately after it was drawn from the cow.

The results of these experiments are discussed on the following pages.

THE EFFICIENCY OF A COVERED PAIL IN EXCLUDING DIRT.

Two kinds of milking pail were used in these experiments. One was a regular open pail, the other was a pail with a cover of special design.* An illustration of the latter is given in the cut below. It is an ordinary milk pail with a closely fitting

cover which has an opening on one side into which is soldered a funnel four inches in diameter, having a wire gauze of fine mesh soldered across the bottom. This funnel extends slightly above and below the cover and slopes somewhat toward the side of the pail. Another funnel, which is loose, fits inside of

*This pail was devised by Mr. F. H. Stadtmuller, of West Hartford, and is used by him in the production of high grade milk. It is also used by Prof. C. L. Beach in the dairy of the Connecticut Agricultural College.

this one. When the pail is to be used a few layers of clean cheese cloth are placed across the opening of the lower funnel and the loose funnel is pushed in to hold the cheese cloth in position. The whole apparatus is simple in structure and can be easily cleaned.

The method of the experiment was to compare the amount of dirt in samples from the two pails. In order to have the conditions as nearly uniform as possible two cows were chosen which gave about equal quantities of milk and required about the same time to milk. These cows stood side by side in the stable, and were milked by the same man each time. On one day cow No. 1 was milked into the open pail and cow No. 2 into the covered pail, and on the next day the order was reversed, cow No. 2 being milked into the open pail and cow No. 1 into the covered pail.

The milk in each pail was then thoroughly stirred and one liter of it was taken out for a sample and tested for the amount of dirt it contained. For this work it was necessary to devise a method whereby the amount of dirt in a given quantity of milk could be determined. So far as known to the writer no work of this kind has been done in this country. Some European investigators have made quantitative determinations of the dirt in market milk, and tests have been made of the different methods of clarifying milk, the most satisfactory results being obtained by the use of centrifugal machines. The latter method was employed in collecting dirt from milk in these experiments.

It is very difficult to remove all the dirt particles from milk without at the same time taking out some of the ingredients of the milk, such as small masses of casein, fat globules, etc. Several methods were tried, the one giving the most satisfactory results being as follows:

The sample of milk was heated to 90° F., and was then run through a separator the bowl of which had also been warmed to 90° by running through it warm filtered water, the amount and temperature of the water necessary for the purpose having been previously ascertained. The milk was poured directly from the sampling flask into the receiving cup of the separator, thus avoiding any error that might arise from pouring it through the supply tank. The sampling flask was then washed

with warm filtered water, and this was also poured into the bowl. After that filtered water at 90° was run through in sufficient quantity to wash out the greater part of the milk from the dirt residue. If the bowl was running at the proper speed before the milk was poured in, and if the speed was maintained till the overflow had entirely ceased, there would be left in the bowl a watery liquid containing the dirt from the sample and a small percentage of milk; but when the work was properly done there would be no fat left in the bowl to interfere with the subsequent filtering.

The contents of the bowl, which consisted of the dirt residue and small quantities of milk, were then collected in a small dish by means of repeated washing, and these were filtered through a filter paper which had previously been dried in a desiccator and weighed. In order to free the residue on the filter paper from all trace of milk it was necessary to wash it for several hours with warm filtered water. After washing until the filtrate showed no traces of cloudiness the paper with the dirt was again dried in the desiccator and weighed, and the weight of the dirt computed.

TABLE 57.

Difference between amounts of dirt in milk from open and covered pails.

Date of Test.	Weight of Dirt per Liter of Milk.			Percentage of dirt excluded by cover.
	In open pail.	In covered pail.	Difference.	
	Gram.	Gram.	Gram.	%
October 15,	0.1613	0.0600	0.1013	62.8
October 16,	0.1410	0.0400	0.1010	71.6
October 17,	0.2185	0.0510	0.1675	81.9
October 22,	0.0690	0.0515	0.0175	25.4
October 23,	0.1040	0.0225	0.0815	78.4
November 4,	0.1350	0.0440	0.0910	67.4
November 5,	0.0600	0.0360	0.0240	40.0
November 15,	0.1063	0.0295	0.0768	72.3
November 16,	0.1095	0.0480	0.0615	56.3
November 18,	0.1110	0.0400	0.0710	64.0
November 16,	0.1200	0.0630	0.0570	48.0
November 20,	0.0785	0.0090	0.0695	89.0
November 21,	0.0835	0.0460	0.0375	45.0
November 22,	0.0465	0.0300	0.0165	36.0
Average,	0.1103	0.0408	0.0695	63.0

The dirt collected in this way of course consisted chiefly of insoluble materials, because most if not all of the soluble material would be dissolved by the use of so much warm water as is necessary to wash the milk out of the dirt residue, and in solution would be thrown out of the separator or would pass through the filter paper. The table above gives the results of a series of tests made as above described.

The figures in the table show that on the average there was in a liter of milk from the open pail 0.11 gram of dirt, and from the covered pail 0.04 gram; indicating that 63 per cent. of the dirt falling into the former pail was kept out of the latter by the cover.

The amount of dirt falling into the open pail was not large in any case. The weights given in the table are for dry dirt, and for insoluble material only; but the total quantities of dirt in the milk were probably not much larger than these. In milk obtained in dairies where the sanitary conditions are poor the amount of dirt is very much larger. These tests were made with cows kept in a stable where the conditions of cleanliness are decidedly better than those of the average dairy barn. With a few exceptions the milk did not look dirty as it stood in the pail.

The reason why the percentage of dirt in the covered pail was as large as was found can probably be explained by the fact that the amount of dirt falling from the cow is greatest directly over that side of the pail on which it is necessary to have the opening in the cover; so that the ratio of the amount of dirt falling on the opening in the cover to the total amount falling upon the pail was probably greater than the ratio of the opening in the covered pail to the exposed surface of the open pail.

THE RELATION BETWEEN THE AMOUNT OF DIRT IN THE MILK AND THE KEEPING PROPERTY OF THE MILK.

Tests were made of the keeping properties of the milk drawn into the two kinds of milking pail, both pails having been thoroughly sterilized by steam before the milking. Representative samples from each pail were placed in sterile vessels, and were kept under the same conditions of temperature, etc., until they had curdled, and the lengths of time until the curdling of the samples were compared. As soon as the first sample

had curdled, however, portions were drawn from both samples and the percentage of acid in them was determined by the use of Farrington's alkaline tablet solution. The results of these tests are given in the following table:

TABLE 58.

Time of curdling, and percentage of acid in both samples when the first one had curdled.

Date of Test.	Length of Time until Curdled.			Percentage of Acid in Milk.		
	Sample from open pail.	Sample from covered pail.	Difference.	Sample from open pail.	Sample from covered pail.	Difference.
	Hours	Hours	Hours	%	%	%
October 23, - - - -	25	25	0	.62	.63	.01
October 24, - - - -	47	23	24	.46	.65	.19
October 25, - - - -	85	74	11	.52	.62	.13
October 26, - - - -	80	75	5	.38	.68	.30
October 28, - - - -	30	30	0	.68	.68	.00
October 29, - - - -	52	47	5	.50	.69	.19
November 4, - - - -	68	65	3	.58	.63	.05
November 5, - - - -	87	80	7	.56	.68	.12
Average, - - - -	59	52	7	.54	.66	.12

In the first test in the table both samples curdled in the same length of time, and the percentage of acid was practically the same in both. The same is true of the test on October 28th. In all the other tests the sample from the covered pail curdled first, the average difference in time for the whole eight tests being seven hours. The percentage of acid in the samples from the covered pail was also greater in each case, except those already noted, than in those from the open pail, the average difference being .12 per cent.

It has already been seen that in the average of fourteen tests the milk from the covered pail contained only about 37 per cent. as much dirt as that in the open pail. The figures above show that in the average of eight tests the milk from the covered pail curdled seven hours sooner and at the time of curdling contained .12 per cent. more acid than the milk from

the open pail. The following table summarizes the results of some tests in which the time of curdling and percentage of acid were observed in samples in which the quantity of dirt was also determined.

TABLE 59.

Comparison of quantities of dirt, time of curdling and percentage of acid in milk from open and covered pails.

Date.	Weight of Dirt per liter of Milk.			Percentage excluded by cover.	Time until Curdled.			Percentage of Acid in Milk.		
	In open pail.	In covered pail.	Difference.		Sample from open pail.	Sample from covered pail.	Difference.	Sample from open pail.	Sample from covered pail.	Difference.
	Gram.	Gram.	Gram.	%	Hrs.	Hrs.	Hrs	%	%	%
Oct. 23,	0.1040	0.0225	0.0815	78.4	25	25	0	.62	.63	.01
Nov. 4,	0.1350	0.0440	0.0910	67.4	68	65	3	.58	.63	.05
Nov. 5,	0.0600	0.0360	0.0240	40.0	87	80	7	.56	.68	.12
Avg.,	0.0997	0.0342	0.0655	65.7	60	57	3	.59	.65	.06

From the table above it will be observed that while in the average of the three tests the milk from the covered pail contained only about 35 per cent. as much dirt as that from the open pail, the former curdled sooner than the latter, and at the time of curdling contained a higher percentage of acid than the milk not curdled.

It would appear then that in these samples the milk which contained the least dirt kept the shortest time.

THE RELATION BETWEEN THE AMOUNT OF DIRT IN THE MILK AND THE GERM CONTENT.

In several of the samples in which the quantities of dirt were determined, tests were also made of the numbers of bacteria in the fresh milk and in the same milk after being kept fifty hours at ordinary temperature. For this purpose plate cultures were made, as in the experiments described by Conn and Esten on preceding pages, and on the plates the total number of bacteria per cubic centimeter as well as the number of acid and liquefying organisms were determined. The following table gives the results of these determinations:

TABLE 60.

Number of bacteria per cubic centimeter in milk from open and covered pails.

Date of Test.	In Fresh Milk.						In Milk at 50 Hours.*					
	Milk from Open Pail.			Milk from Covered Pail.			Milk from Open Pail.			Milk from Covered Pail.		
	Total.	Acid Species.	Liquefiers.	Total.	Acid Species.	Liquefiers.	Total.	Acid Species.	Liquefiers.	Total.	Acid Species.	Liquefiers.
November 15, - - - -	11525	7575	412	15250	10575	312	222500	162500	5500	87000	85900	100
November 16, - - - -	6900	3688	500	2700	1888	200	175500	173100	2400	15900	11000	1700
November 18, - - - -	30250	20900	350	4750	3000	150	248750	241250	0	1121000	9500	0
November 19, - - - -	6850	1800	400	13400	2650	385	205000	63000	1500	15916	9250	500
November 20, - - - -	4300	1460	375	3913	1600	600	1267500	†	3250	1836250	†	6000
November 21, - - - -	3788	475	388	4275	1200	375	1258000	†	15250	4026000	†	2500
November 22, - - - -	2963	800	138	3188	838	250	548750	†	10160	66000	†	14400
Average, - - - -	9510	5240	366	6780	3100	325	560859	—	5430	1024009	—	3600

* For actual numbers add three ciphers to the figures in the last six columns.

† The numbers were so large in these three tests that they could not be determined by the dilutions used.

The figures in the table above show that the total number of bacteria in the fresh milk from the covered pail averaged about 71 per cent. of that in the milk from the open pail; the number of acid producing bacteria in the former averaged about 59 per cent. of that in the latter; the average number of liquefiers was nearly the same in the samples from the two kinds of milking pail. That is, about 29 per cent. of the total bacteria, and about 41 per cent. of the acid producing organisms, were kept out by the cover.

The quantities of dirt contained in the samples included in the table above are given in Table 57 preceding. According to the figures there given, there was only about 41 per cent. as much dirt in the milk from the covered pail as in that from the open pail, on the days of the tests included in Table 60.

A comparison of the quantities of dirt in the different samples with the numbers of bacteria in the fresh milk would indicate that the latter are not in proportion to the former. Thus while there was, on the average, only about 41 per cent. as much dirt in the samples from the covered pail as in those from the open pail, the total number of bacteria in the former was 71 per cent. of that in the latter. This may be due to a difference in the character of the dirt in the different samples, being in the one case more soluble perhaps, and thus allowing a larger number of bacteria to become disseminated in the milk.

In four of the tests the total numbers of bacteria in the samples that had been kept at ordinary temperature for fifty hours were considerably larger in the samples from the open pail than in those from the covered pail; in the third and sixth tests the numbers were very much larger in the milk from the covered pail, thus accounting for the larger average for the latter.

In the first four tests the number of acid producing bacteria was decidedly larger at fifty hours in the samples from the open pail than in those from the covered pail. In the last three tests the organisms had increased so rapidly in both samples that the numbers could not be determined on the plates.

It will be noticed that the number of bacteria in the fresh milk bears no relation to the number in the milk at a later period. Thus in the samples from the open pail on November

18 the total number in the fresh milk was 30,250, and in the same sample after fifty hours there were 248,750,000; while on November 21 the number in the fresh milk was 3,788, and in the same milk after fifty hours it was 1,258,000,000. Similarly in the samples from the covered pail, in the fresh milk on November 18 the total number of bacteria was 4,750, and on November 19 it was 13,400; but in the same samples after fifty hours the number in the former had increased to 1,121,000,000, while in the latter it was only 15,916,000. Again, on November 18 the number of bacteria in the fresh milk from the open pail was over six times as large as that for the covered pail, but after fifty hours the number in the latter sample was nearly five times that in the former.

THE RELATION OF THE GERM CONTENT TO THE KEEPING PROPERTIES OF THE MILK.

In the samples of milk included in Table 60 above, tests were made of the percentage of acid in the milk that had been kept for fifty hours, and the length of time until the samples curdled was noted as closely as possible; in some cases the curdling occurred during the night, so that the exact time could not be ascertained. The results of these observations are given in the table below.

TABLE 61.

Percentage of acid in milk kept for 50 hours, and length of time until curdling.

Date of Test.	Perctg. of Acid in Milk at 50 Hours.*			Time until Curdled.		
	Sample from open pail.	Sample from covered pail.	Difference.	Sample from open pail.	Sample from covered pail.	Difference.
	%	%	%	Hrs.	Hrs.	Hrs
November 15,	.27	.30	+.03	63	89†	26
November 16,	.29	.22	—.07	52†	85	33
November 18,	.67	.63	—.04	54	54	0
November 19,	.56	.40	—.16	56	60	4
November 20,	.43	.51	+.08	57	55	2
November 21,	.53	.78	+.25	52	40†	12
November 22,	.37	.76	+.39	76	54	22
Average,	.44	.51	+.07	59	62	3

* Samples were kept at constant temperature of 70°F.
† These samples curdled during the night.

In three of the samples the percentage of acid was somewhat smaller, and in four it was larger in the milk from the covered pail than in that from the open pail, the difference in the last two tests being quite decided. In the average of the seven tests it was about 16 per cent. larger for the covered pail.

The number of hours until the milk curdled was greater for the sample from the covered pail in three tests, less in three other tests and the same in one test, the average difference being about three hours.

A comparison of the results given in Tables 60 and 61 will give some indication of the relation of the germ content of the different samples of milk to their keeping properties. From Table 60 it may be seen that in the first test the number of bacteria in the sample from the covered pail was 15,250, while the number in the sample from the open pail was 11,525; and in Table 61 it will be observed that the latter curdled a whole day in advance of the former. In the third test the sample from the open pail, having 30,250 bacteria, remained uncurdled the same length of time as the sample from the covered pail, which contained but 4,750 bacteria. Again in the last test, where there was a relatively small difference between the numbers of bacteria in the two samples, there was a difference of twenty-two hours in the time of curdling. It would seem then from the results of these tests that the number of germs present in the fresh milk is but little indication of the length of time the milk will keep before curdling; nor does the number of acid bacteria in the fresh milk serve as a much better indication of its keeping properties.

THE EFFICIENCY OF THE COVERED PAIL AS COMPARED WITH STRAINING MILK FROM AN OPEN PAIL.

A number of tests similar to those described above were made upon the efficiency of straining the milk immediately after it was drawn. As soon as one cow was milked into the open pail, the milk was stirred and a liter of it taken for a sample; then the rest of the milk was strained through two thicknesses of fine cheese cloth supported by a wire gauze (the same as that used on the covered pail) and a liter of the strained milk was taken out for a sample. The two samples were then tested for the amount of dirt contained, the number of bacteria in the

fresh milk and in the milk after standing for fifty hours at ordinary temperature, the percentage of acid in the milk after fifty hours, and the length of time until the milk curdled. The results of a series of these tests are given in the following tables.

THE REMOVAL OF DIRT BY STRAINING.

The quantities of dirt in the milk before and after it was strained are given in the following table.

TABLE 62.

Quantities of dirt in milk before and after straining.

Date of Test.	Weight of Dirt per Liter of Milk.			Perctg. of dirt removed by strain'g.
	In unstrained sample.	In strained sample.	Difference.	
	Gram.	Gram.	Gram.	%
November 23,	0.0245	0.0020	0.0225	91.8
November 25,	0.0895	0.0470	0.0425	47.5
November 26,	0.0555	0.0495	0.0060	10.8
November 27,	0.0515	0.0295	0.0220	42.7
November 30,	0.0725	0.0360	0.0365	50.3
December 5,	0.0710	0.0270	0.0440	61.9
December 6,	0.0505	0.0310	0.0195	38.6
Average,	0.0593	0.0317	0.0276	46.6

The smallest difference between the quantities of dirt in the two samples was on November 26, when only about 11 per cent. of the dirt was removed by the strainer; the largest difference was on November 23, when about 92 per cent. was removed by straining. In the average of seven tests the amount of dirt strained out of the milk was about 47 per cent. of that in the milk not strained.

The amount of dirt which could be removed by the strainer depended largely upon the nature of the dirt. That in the sample of November 23, in which the percentage strained out was the largest, consisted mainly of hairs, skin scales from the teats and udder, particles of hay, chaff and other materials of a coarse, insoluble nature; there was but little manure or other soluble material in this sample, while on the other hand in the sample on November 26 where the percentage strained out was

TABLE 63.

Number of bacteria in fresh milk and after 50 hours.

Date of Test.	In Fresh Milk.						In Milk after 50 Hours.*					
	Not Strained.			Strained.			Not Strained.			Strained.		
	Total Number.	Acid Species.	Liquefiers.	Total Number.	Acid Species.	Liquefiers.	Total Number.	Acid Species.	Liquefiers.	Total Number.	Acid Species.	Liquefiers.
November 23, - - - -	3600	1500	225	3600	1900	213	2090750	55000	1500	2342000	1327000	5500
November 25, - - - -	7400	2600	1500	6900	2600	1400	49600	10500	16000	38500	12500	5500
November 26, - - - -	12800	4100	875	10500	3500	500	†	†	†	†	†	†
November 27, - - - -	5100	1300	400	4100	1100	400	†	†	†	†	†	†
November 30, - - - -	39500	9500	550	32000	5700	450	†	†	†	60000	10750	11250
December 5, - - - -	8800	850	2100	11375	1450	2900	103125	29875	14500	474000	467800	4800
December 6, - - - -	2800	460	460	2700	575	312	153387	133250	17937	165600	151250	24400
Average, - - - -	11400	2900	873	10150	2400	882	599215	57156	11384	755025	489673	10050

* For actual numbers, add three ciphers to figures in last six columns.

† No tests made.

the smallest the dirt contained a large proportion of manure which became more or less disintegrated and dissolved in the milk and could therefore pass through the strainer.

According to the results given in Table 57 the amount of dirt in the milk from the covered pail was in the average of fourteen tests but 37 per cent. of that in the milk from the open pail. That is, 63 per cent. of the dirt that would fall into an open pail was kept out by the cover, whereas in the tests here described only 47 per cent. was removed by straining.

NUMBER OF BACTERIA IN THE MILK.

The total number of bacteria and the number of acid species and liquefiers in both samples of milk were determined in the fresh milk and again in several of the samples after they had been kept for fifty hours. The results of the tests are given in Table 63 above.

In every test but one the total number of bacteria in the strained milk was smaller than that in the milk not strained, the average being about 11 per cent. less in the former. The numbers of acid producing bacteria and liquefiers were in some tests larger and in others smaller in the strained milk, the number of acid bacteria averaging about 17 per cent. less than in the milk not strained. In the milk after fifty hours the number of acid bacteria was very much larger in the strained milk.

If Table 60 is compared with Table 63 to determine the relative value of the straining and the use of the covered pail, it will be seen that the covered pail appears to be somewhat superior. The cover reduced the average number of bacteria from 9,500 to 6,700 per cubic centimeter in fresh milk, whereas the straining had considerable less influence, reducing it from 11,400 to 10,100 only, indicating that straining through cheese cloth after milking is not so efficient a means of preventing the entrance of bacteria as using the covered pail.

THE KEEPING PROPERTIES OF THE MILK.

After the milk had been kept for fifty hours at a temperature of 70° F. the percentage of acid was determined in both samples; they were then allowed to stand until the milk had curdled, and the length of time noted. These results are given in the following table.

TABLE 64.

Percentage of acid in milk after 50 hours, and length of time until curdling.

Date of Test.	Perctg. of Acid in Milk at 50 Hours.			Length of Time until Curdled.		
	Not strained.	Strained.	Difference.	Not strained.	Strained.	Difference.
	%	%	%	Hrs.	Hrs.	Hrs.
November 23,	.75	.79	+.04	42	42	0
November 25,	.46	.42	—.02	57	55	2
November 26,	*	*	*	35	35	0
November 27,	*	*	*	65	65	0
November 30,	.22	.20	—.02	76	66	10
December 5,	.25	.63	+.38	89	54	35
December 6,	.66	.64	—.02	50	50	0
Average,	.46	.54	+.08	59	52	7

* Test not made.

In some tests the percentage of acid was slightly larger in the milk not strained; in others it was larger in the strained milk, in one test being decidedly larger, and averaging .08 per cent. larger. The length of time until curdling was the same for both samples in four tests, but was greater in three tests for the milk not strained, the average difference being seven hours. Likewise in the tests with the covered pail the milk from the open pail curdled on the average seven hours later than the milk from the covered pail.

SUMMARY.

Two sets of tests were made. In the one case milk drawn into an open pail was compared with milk drawn into a pail with a cover devised for excluding dirt during milking. In the other case milk drawn into an open pail was compared with the same milk strained immediately after the milking.

The amount of dirt in the milk from the covered pail was only 37 per cent. of that in the open pail; while the amount of dirt in the strained milk was 54 per cent. of that in the milk not strained. The differences in the two samples varied more widely in the latter tests than in the former. In the straining the amount of dirt removed depended more largely upon the nature of the dirt.

In the fresh milk from the covered pail the total number of bacteria was about 71 per cent., and the number of acid bacteria about 59 per cent. of those in the fresh milk from the open pail. In the fresh strained milk the total number of bacteria was 89 per cent. and the number of acid bacteria 83 per cent. of those in the milk not strained.

After the milk had stood for fifty hours at constant temperature of 70° F. the average for the total number of bacteria was larger in the milk from the covered pail than in that from the open pail; while the average for the acid producing species was larger in the latter than in the former. In the strained milk both the total number and the number of acid bacteria were larger than in the milk not strained.

The milk from the covered pail curdled sooner than that from the open pail, the average difference being about seven hours; likewise the strained milk curdled sooner than the milk not strained, the average difference being also about seven hours. This fact, however, is of but little moment since any of these samples had they been kept at the usual temperatures for handling milk would have remained sweet longer than milk is usually kept.

The results of these tests would seem to indicate that the covered pail is more efficient for the production of pure milk than straining milk drawn into an open pail. It is quite evident also that to keep the dirt out of the milk in the first place is much better than straining it out after the milking. A considerable portion of the dirt dissolves quickly in the warm milk and thus introduces a contamination that cannot be strained out.

It has already been pointed out that these tests were made in a dairy where the conditions of cleanliness are good. The amount of filth such as dirt, hair, etc., that is frequently removed by a separator from milk of ordinary dairies as delivered in cities is frequently appalling. It would be interesting to test the efficiency of the covered milk pail in dairies where the sanitary conditions are not so good as they were in these tests.

FIELD EXPERIMENTS WITH FERTILIZERS.

BY C. S. PHELPS.

The field experiments conducted by the Station during 1901 were in continuation of those of preceding years. It has been the policy of the Station to repeat these experiments for a number of years on the same sets of plots, making each year's experiments as nearly as possible duplicates of those of the year preceding, in the belief that in this way the value of the results would be increased. The experiments now in progress at the Station include the following:

1. Special nitrogen experiments on corn, cow peas and soy beans, for the purpose of studying the effects of nitrogen in different quantities and combinations when used as a fertilizer upon the yields and the composition of the crop.

2. A soil test on the Station land, with a rotation of crops, for the purpose of studying the deficiencies of the soil and the demands of different crops for the various ingredients of fertilizers.

3. An experiment on soil improvement, for the purpose of comparing the relative economy of (1) stable manure, (2) a "complete chemical fertilizer," and (3) green manuring alone and in connection with mineral fertilizers, for improving a soil apparently deficient in organic matter and in nitrogen.

Accounts of these experiments are given in the annual reports of the Station year by year, and from time to time the results of the experiments for a number of years are summarized and discussed in detail.* The present report gives a review of the work for 1901. The special nitrogen experiments and the soil test are described in this article; the experiment on soil improvement in the article following.

* See Storrs Experiment Station Reports, 1892, p. 67, 1898, p. 113 and 1889, p. 168.

SPECIAL NITROGEN EXPERIMENTS.

The special nitrogen experiments on corn, cow peas and soy beans have been continued since 1895 on a set of plots that had been used for similar experiments, but with other crops, for a number of years before this series was begun. The purpose of the experiments is to study the effects of nitrogenous fertilizers upon the yields of the different crops and the proportions of nitrogen in them. The plan of the experiments, which has been described in detail in previous reports,* consists, briefly, in growing the several crops in a series of plots all of which, except two without fertilizer, are supplied with uniform quantities of mineral fertilizers, supplying phosphoric acid and potash in definite amounts, and with varying quantities of nitrogenous fertilizers supplying nitrogen in different amounts, and in comparing the weights and the composition of the crops from the different plots. The general methods of the experiment are illustrated and explained by the diagram and the discussion following.

The field used for the experiments was divided into ten long, rather narrow, parallel plots, which are indicated in the diagram by the numbers 0, 7, 8, etc., at each end of the plots. Those designated as 0 and 00 have received no fertilizer for twelve years, while those designated as 6*a* and 6*b* have received each year during the same period only the fertilizers called for convenience "mixed minerals," which consist of dissolved boneblack at the rate of 320 pounds per acre, equivalent to 53 pounds of phosphoric acid, and muriate of potash 160 pounds per acre, equivalent to 82 pounds of potash. Plots 7, 8, and 9 have received in addition to the mixed minerals respectively 160, 320 and 480 pounds of nitrate of soda per acre, equivalent to 25, 50 and 75 pounds of nitrogen, while the nitrogenous fertilizer added to the mixed minerals on plots 10, 11 and 12 consist of 120, 240 and 360 pounds of sulphate of ammonia per acre, supplying 25, 50 and 75 pounds of nitrogen.

The land on which these plots are laid out has considerable slope, so that with heavy rains there is some washing of the surface soil. Although this washing runs mainly lengthwise of the plots, it doubtless interferes somewhat with the accuracy

* See Reports for 1898 and 1899.

Diagram illustrating the arrangement of the plots, the method of dividing the plots into sections, and the kind of crop planted on each section.

The plots are indicated by numbers, the sections by letters.

EAST.

	A	B	C	D	E	F	
6*b*	Corn.	Soy beans.	Cow peas.	Cow peas.	Soy beans.	Corn.	6*b*
00	Corn.	Soy beans.	Cow peas.	Cow peas.	Soy beans.	Corn.	00
12	Corn.	Soy beans.	Cow peas.	Cow peas.	Soy beans.	Corn.	12
11	Corn.	Soy beans.	Cow peas.	Cow peas.	Soy beans.	Corn.	11
10	Corn.	Soy beans.	Cow peas.	Cow peas.	Soy beans.	Corn.	10
6*a*	Corn.	Soy beans.	Cow peas.	Cow peas.	Soy beans.	Corn.	6*a*
9	Corn.	Soy beans.	Cow peas.	Cow peas.	Soy beans.	Corn.	9
8	Corn.	Soy beans.	Cow peas.	Cow peas.	Soy beans.	Corn.	8
7	Corn.	Soy beans.	Cow peas.	Cow peas.	Soy beans.	Corn.	7
0	Corn.	Soy beans.	Cow peas.	Cow peas.	Soy beans.	Corn.	0
	A	B	C	D	E	F	

NORTH. (left side) SOUTH. (right side)

WEST.

of the results. Plans have already been made for experiments on a more nearly level piece of land, which is now being cropped without manure in order to prepare the soil for the purpose.

Each of the larger plots contains one-eighth acre of land, and is sub-divided into six sections 1-50 acre each by paths crossing the lots from east to west, as indicated in the diagram. The sections on each plot are designated by the letters A–F shown at the sides of plots o and *6b* in the diagram. It is generally understood that the effects of fertilizers on the yields of crops could probably be more accurately studied on the large plots than on the smaller sections, because in the former case the effects of irregularities of the soil upon the yield would be less marked. In these experiments, however, the effects of nitrogen of fertilizers upon the proportions of nitrogen compounds (protein) in the crop is believed to be the more important question, and this can perhaps be studied as well upon the smaller sections as upon the larger plots. The advantage gained in subdividing the plots into sections is in the opportunity to study several different crops at the same time under like conditions, thus giving the results from one set of experiments a wider application.

The name of the crop grown on each section is shown in the diagram. Two series of sections, A and F, were planted with the same variety of corn; two series, B and E, with soy beans, and two series, C and D, with cow peas. In recording the results with the cow peas and the soy beans the two series of sections for each crop were treated as if there was but one series; that is, the yields on corresponding sections of B and E, and of C and D, were added together and samples were taken from the combined crop. In the case of the corn, however, the results have been kept separate, because lime was used on one of the two series of sections and not on the other, as will be explained later.

Explanation of tables.—Two tables of data are given in connection with the discussion of the results for each crop. The first table in each case gives the weight and cost of fertilizers per acre, the weights of crop per section and the calculated weights per acre, and the increase in yield from the sections with fertilizers over the average of the yields from the sections

without fertilizer. In the case of the cow peas the yields per section are the weights of the green crop when harvested. The grain of the corn and the soy beans were dried in the barn and weighed when thought to be in good condition for grinding into meal. The corn stover was field cured and then weighed, while the soy bean straw was discarded because most of the leaves had dropped off before the seed ripened, leaving only the bare stalks and the pods.

The cost of the fertilizers per acre as given in the tables represents the cash market value of the various ingredients when sold in the form of raw materials, the cost of mixing, transportation and agents' profits being left out of consideration. The costs are calculated from the weights of the ingredients per acre, as used, and the value of the ingredients as adopted by the New England Experiment Stations. The valuations of the different ingredients used in the experiments of 1901 were as follows:

	Per Pound.
Nitrogen in nitrate of soda, - - - - -	14 cts.
Nitrogen in sulphate of ammonia, - - - -	16½ "
Organic nitrogen (in dried blood), - - - -	16½ "
Phosphoric acid (soluble), - - - - - -	5 "
Potash in muriate of potash, - - - - -	4½ "

The second table in each case gives the total yields of crop per acre, the percentages of water-free substance in the crop as weighed to obtain the yields, the percentages of protein (N. $\times$ 6.25) in the dry matter, and the estimated yields of dry matter and of protein per acre. The amounts of dry matter per acre are calculated by multiplying the total weights of crop per acre as harvested by the percentage of dry matter, and the amounts of protein per acre are calculated by multiplying the estimated weight of dry matter per acre in the crop from the various sections by the corresponding percentages of protein. The last two columns show the percentages of the yields of dry matter and of protein for each section when the yields from the sections of the mineral plots are taken as a basis (100).

Chemical analyses.—The only chemical determinations made were those of moisture and total nitrogen. Water-free substance was estimated by difference. The total protein was estimated from the total nitrogen by multiplying by the factor

6.25. This factor has been commonly used by chemists on the assumption that protein substances in general contain practically 16 per cent. of nitrogen, although it is understood that the percentage of nitrogen varies and that not all the nitrogen present is in the form of true proteids. In these experiments no attempt has been made to separate the true proteids from the non-proteid compounds, nor has the possible presence of nitrates been taken into account in estimating yields of protein. The amount of non-proteid or non-albuminoid compounds is usually quite small in crops of this class, and the chemical methods in use for separating them from the true proteids are not satisfactory. Tests for nitrates were made in connection with the analyses of the crops from the field and pot experiments in 1900, but only traces were found. It seems probable that in field experiments where only moderate quantities of nitrogenous fertilizers are used the presence of nitrates in the crop may be safely left out of account. For these reasons, and also because the use of the factor 6.25 is believed to be sufficiently accurate for practical purposes, protein has been estimated in this way, in order that the results of these experiments may be directly comparable with those reported in previous years, in which the same factor was employed.

EXPERIMENTS WITH CORN.

As shown in the diagram on page 124, corn is grown on the two series of sections lettered A and F. The same kind of corn, a Rhode Island white cap, is grown on both series of sections. Seed is saved each year from each section for planting on the same section the following year. The original seed planted on series F was obtained at the beginning of the experiment in 1895, and that used on series A was obtained from the same farmer in 1898.

Previous to 1898 both series of sections had been fertilized alike. It had been observed, however, that the corn did not seem to thrive as well on the plots supplied with sulphate of ammonia, where the largest quantities were used, as on those supplied with nitrate of soda, although the quantities of actual nitrogen correspond in the two series of plots. It was thought that the cause for the poorer growth on the sulphate plots might be possibly a deleterious acidity of the soil, resulting

perhaps from the acid residue left behind when the nitrogen was taken from the sulphate of ammonia. It was also thought that such an acidity might be corrected by lime. In accordance with these hypotheses, 40 pounds of air slacked lime was applied in 1898 on each section in series A, but none on series F. The purpose of applying lime upon all the plots in the series was that the comparison might be made as usual between the yields from the different plots, and the purpose of applying lime to one series of sections and not to the other was that the effects of the lime might be observed in comparing the yields from the two series upon which the conditions were similar in all respects except for the application of the lime. A comparison of yields from the sections with the lime with those from the sections without lime is given beyond in the discussion of the yields of corn.

TABLE 65.

SPECIAL NITROGEN EXPERIMENTS ON WHITE FLINT CORN (SERIES A).

Weight and cost of fertilizer per acre, total crop, and increase of crop over that of nothing plots.

No. of plot.	Fertilizers per Acre. Kind.	Weight.	Cost.	Yield per Sec. 1-50 Acre. Shelled corn.	Yield per Sec. 1-50 Acre. Stover.	Estim't'd Yield per Acre. Shelled corn.	Estim't'd Yield per Acre. Stover.	Gain over nothing plots.
		Lbs.	$	Lbs.	Lbs.	Bu.	Lbs.	Bu.
0	Nothing, - - - - - -	—	—	00.5	11.5	00.4	575	—
7	Mixed Minerals, as No. 6*a*, - Nitrate of Soda (25 lbs. N.), -	480 160	9.64	13.0	44.5	11.6	2225	6.7
8	Mixed Minerals, as No. 6*a*, - Nitrate of Soda (50 lbs. N.), -	480 320	13.14	33.0	51.0	29.5	2550	24.6
9	Mixed Minerals, as No. 6*a*, - Nitrate of Soda (75 lbs. N.), -	480 480	16.64	45.0	48.0	40.2	2400	35.3
6*a*	Dis. Bone-black, } Mixed - Mur. of Potash, } Minerals, -	320 160	6.14	17.0	31.5	15.2	1575	10.3
10	Mixed Minerals, as No. 6*a*, - Sulph. of Am. (25 lbs. N.), -	480 120	10.27	32.0	57.0	28.6	2850	23.7
11	Mixed Minerals, as No. 6*a*, - Sulph. of Am. (50 lbs. N.), -	480 240	14.39	50.0	66.0	44.6	3300	39.7
12	Mixed Minerals, as No. 6*a*, - Sulph. of Am. (75 lbs. N.), -	480 360	18.52	54.0	72.0	48.2	3600	43.3
00	Nothing, - - - - - -	—	—	10.5	15.0	9.4	750	—
6*b*	Mixed Minerals, as No. 6*a*, -	480	6.14	29.0	49.0	25.9	2450	21.0

TABLE 66.

SPECIAL NITROGEN EXPERIMENTS ON WHITE FLINT CORN (SERIES F).

Weight and cost of fertilizers per acre, total crop, and increase of crop over that of nothing plots.

No. of plot.	Fertilizers per Acre. Kiud.	Weight.	Cost.	Yield per Sec. 1-50 Acre. Shelled corn.	Yield per Sec. 1-50 Acre. Stover.	Estim't'd Yield per Acre. Shelled corn.	Estim't'd Yield per Acre. Stover.	Gain over nothing plots.
		Lbs.	$	Lbs.	Lbs.	Bu.	Lbs.	Bu.
0	Nothing, - - - - - -	—	—	2.0	13.0	1.8	650	—
7	Mixed Minerals, as No. 6*a*, - - Nitrate of Soda (25 lbs. N.), -	480 160	9.64	10.0	34.5	8.9	1725	4.4
8	Mixed Minerals, as No. 6*a*, - - Nitrate of Soda (50 lbs. N.), -	480 320	13.14	27.0	37.5	24.1	1875	19.6
9	Mixed Minerals, as No. 6*a*, - - Nitrate of Soda (75 lbs. N.), -	480 480	16.64	40.0	35.5	35.7	1775	31.2
6*a*	Dis. Bone-black, } Mixed Mur. of Potash, } Minerals, -	320 160	6.14	12.5	37.0	11.2	1850	6.7
10	Mixed Minerals, as No. 6*a*, - - Sulph. of Am. (25 lbs. N.), - -	480 120	10.27	32.0	50.0	28.6	2500	26.0
11	Mixed Minerals, as No. 6*a*, - - Sulph. of Am. (50 lbs. N.), - -	480 240	14.39	40.0	45.5	35.7	2275	31.2
12	Mixed Minerals, as No. 6*a*, - - Sulph. of Am. (75 lbs. N.), - -	480 360	18.52	22.0	21.5	21.4	1075	16.9
00	Nothing, - - - - - -	—	—	8.0	17.0	7.1	850	—
6*b*	Mixed Minerals, as No. 6*a*, - -	480	6.14	15.0	40.0	13.4	2000	8.9

THE AMOUNTS OF NITROGEN IN THE FERTILIZER AND THE TOTAL YIELDS OF CROP.

Tables 65 and 66 give the weight and cost of fertilizer per acre as used on the different plots, the yields of corn and stover per section and the calculated yields per acre, and the increase in yield of grain on the fertilized sections over the average of the yields on the two sections without fertilizer. Table 65 gives the results from sections of series A, and Table 66 those from sections of series F. The yields per section there given are the weights of the crops as determined; the yields per acre are calculated from these and the size of the sections. The last column of the table shows the effects of the different fertilizers on

the yields of grain by the increase of the yield per acre obtained on the fertilized sections over the average of the yield from the sections of the two plots not fertilized.

The yields on the sections of plots 0 and 00 were of course very light, as these plots have had no fertilizer for the past twelve years. The yields on the sections of plot 0 were especially light, practically no ears developing; this was probably due in part to the fact that the soil on this plot had washed considerably as a result of severe rains during the previous winter. A similar condition seems to have affected the yields on plot 7, next to plot 0. The ground was more sloping on these plots than on most of the others.

The yields obtained on the sections of plots 6*a* and 6*b*, supplied with mineral fertilizer (phosphoric acid and potash), were considerably better than those obtained where no fertilizer was used. These plots have not been supplied with nitrogen in the fertilizer since the field was first laid out for experiments in 1890. The lack of available nitrogen in the soil caused a pale yellow color in the crop during the season of growth, and resulted in a small yield of ears. The growth of stover does not seem to have been much less on these sections than on those where nitrogen was used; but while the yields of stover averaged as much as on several of the plots supplied with nitrogen in addition to the minerals, the yields of grain were very much less than on most of the plots having nitrogen.

The plots supplied with nitrogen were in two groups of three plots each, the successive plots in each group receiving respectively 25, 50 and 75 pounds of nitrogen per acre, in addition to the mineral fertilizers which were uniform for all fertilized plots. In one group—plots 7, 8 and 9—the nitrogen was supplied in nitrate of soda, and in the other group—plots 10, 11 and 12—in sulphate of ammonia. On both series, A and F, the yields on the sections of plot 7, where the smallest rations of nitrate of soda were used, were quite light, being very much less than on the corresponding sections of plot 10 where the same quantity of nitrogen was used in the form of sulphate of ammonia. This is perhaps due in part to the fact that the soil on plot 7 was washed, as was pointed out above. On the sections of plots 8 and 11, where 50 pounds of nitrogen per acre

was used, there was quite a marked increase in the yields, whether the nitrogen was supplied in nitrate of soda or in sulphate of ammonia. As in the case of plots 7 and 10, however, the largest yield was again from the sections with the sulphate of ammonia; this unusual condition may possibly be due to the wetness of the season, resulting in a greater leaching and loss of the nitrate than of the sulphate. On the sections of plots 9 and 12, where the largest rations of nitrogen were used, the yields of grain were, with one exception, the largest of those on any of the sections. The gradual increase in yields corresponding to the amounts of nitrogen used points out the importance of this element in the growth of corn. It is of interest to note, however, that the yields were everywhere less than on the corresponding sections in 1900. This was probably due to the character of the season in 1901, the exceptionally heavy rains which characterized it probably favoring the leaching out of the more soluble fertilizing ingredients, especially the nitrogen, while in 1900 the season was drier and the storms were not generally characterized by heavy rainfalls. However, the yields obtained in the experiments of the later years are in general smaller than those of earlier years. This difference may be due in part to the absence of organic matter in the soil which when present would tend to retain the nitrogen until the crop could use it. This lack of organic matter is suggested by the fact that for twelve years the soil has been supplied with chemical fertilizer only, and as very little organic matter was supplied the amount previously in the soil has probably been gradually reduced as the period of the experiment was extended.

Comparison of yields from sections with and without lime.— From the results in Table 66 it will be observed that while the yields from sections F of plots 10 and 11, with the small and medium amounts of nitrogen in sulphate of ammonia, were considerably greater than those from the corresponding sections of plots 7 and 8 with the same quantities of nitrogen in nitrate of soda, the yield from section F of plot 12 with the large amount of nitrogen in sulphate of ammonia was considerably less than that from section F of plot 9 with the same amount of nitrogen in nitrate of soda. Inasmuch as the two

groups of plots thus compared are fertilized exactly alike, except that the source of nitrogen in one case is nitrate of soda and in the other sulphate of ammonia, the yields from the corresponding plots of the groups might be expected to correspond somewhat more closely than is here indicated, provided the fertilizers used had like beneficial action on the growth of the crops. It has already been explained that the differences in the experiment of 1901 between the yields from plots 7 and 8 and those from plots 10 and 11 are very unusual, and are probably due to the character of the season. The discrepancies pointed out between the yields from plots 9 and 12 are quite usual, however, from which it would seem that the hypothesis on a preceding page that a deleterious acidity of the soil resulted from the use of large amounts of sulphate of ammonia would seem to be reasonable. The effect of the application of lime for the correction of this acidity of the soil may be seen by comparing the results tabulated below.

TABLE 67.

Comparison of yields of corn and stover from sections with and without lime.

Fertilizers.	No. of Plot.	Yields per Acre. Series F. Without Lime. Shelled corn.	Yields per Acre. Series F. Without Lime. Stover.	Yields per Acre. Series A. With Lime. Shelled corn.	Yields per Acre. Series A. With Lime. Stover.
Nitrate of Soda group,	7	8.9	1725	11.6	2225
	8	24.1	1875	29.5	2550
	9	35.7	1775	40.2	2400
Sulphate of Ammonia group,	10	28.6	2500	28.6	2850
	11	35.7	2275	44.6	3300
	12	21.4	1075	48.2	3600

From the results summarized in the table above it will be seen that while the yield from section of plot 12 with the largest quantity of nitrogen in sulphate of ammonia was smaller than that from plot 9 with the same quantity of nitrogen in nitrate of soda, the yield from section A of plot 12, upon which the lime was applied, was larger than that from the corresponding section of plot 9, also with the lime. This would

seem to indicate that the application of the lime to the soil with the large quantity of the sulphate was beneficial. It will be noticed, however, that in all cases except one the yields were greater on the sections of series A than on corresponding sections of series F, which would suggest that the lime had some direct beneficial effect upon the fertility of the soil, in addition to its action in neutralizing acidity; for on the nitrate of soda plots the residue from the nitrate in accumulating would tend to cause an alkaline rather than an acid condition of the soil.

The results seem to favor the hypothesis that a soil may become injuriously acid by the continued use year after year of large quantities of sulphate of ammonia, and that lime may be employed to correct the acidity. They also seem to indicate that lime may often prove beneficial in other ways than in the correction of acidity of the soil, especially where commercial fertilizers have been used for a long time without stable manure or organic material.

The amounts of nitrogen in the fertilizer and the proportions of protein in the crop.—The results given in Tables 68 and 69 show the effects of the fertilizer on the yields of dry substance of the crop, and on the proportions and yield of protein. They are intended to show particularly the effects of the nitrogen in the fertilizer on the yields of protein and its influence on the feeding value of the crop. The data included in the tables are the yields of crop per acre as harvested, the percentages of dry matter and of protein, and the calculated yields of dry matter and of protein per acre. In the last two columns of the table the yields of dry matter and of protein per acre from the plots where the different amounts of nitrogen were used in addition to the minerals are given in percentages of the average of yields from the two plots where only mineral fertilizers were used. This gives an opportunity to observe the effect of nitrogen on the total yields of protein.

In discussing the results it has seemed best to omit the consideration of plots where no fertilizers were used, as the results are probably abnormal. The percentages of nitrogen in the crops grown without fertilizer were in some cases greater than where fertilizers were used. This seems to have been due to

Table 68.

SPECIAL NITROGEN EXPERIMENTS ON WHITE FLINT CORN (SERIES A).

Percentages and pounds per acre of dry matter and of protein in the grain and stover.

No. of Plot.	Fertilizers per Acre. Kind.	Fertilizers per Acre. Weight.	Portion of crop.	Weight at harvest per acre.	Dry matter.		Protein in dry matter. N × 6.25.		Percentage of yield on basis of yield from mineral plots. Dry matter.	Percentage of yield on basis of yield from mineral plots. Protein.
		Lbs.		Lbs.	%	Lbs.	%	Lbs.	%	%
0	Nothing, - - -	—	Grain,	25	85.0	21.3	10.4	2.2	2.3	3.1
			Stover,	575	70.1	403.1	8.3	33.5	29.6	48.5
			Total,	**600**	—	**424.4**	—	**35.7**	**18.4**	**25.6**
7	Mixed Min's, as No. 6*a*,	480	Grain,	650	82.8	538.2	9.1	49.0	57.3	69.6
	Nit. of Soda (25 lbs. N.),	160	Stover,	2225	56.2	1250.5	5.3	66.3	91.8	95.9
			Total,	**2875**	—	**1788.7**	—	**115.3**	**77.7**	**82.7**
8	Mixed Min's, as No. 6*a*,	480	Grain,	1650	80.1	1321.7	10.2	134.8	140.6	191.5
	Nit. of Soda (50 lbs. N.),	320	Stover,	2550	64.4	1642.2	6.1	100.2	120.6	145.0
			Total,	**4200**	—	**2963.9**	—	**235.0**	**102.7**	**168.5**
9	Mixed Min's, as No. 6*a*,	480	Grain,	2250	81.8	1840.5	10.2	187.7	195.8	266.6
	Nit. of Soda (75 lbs. N.),	480	Stover,	2400	71.3	1711.2	6.1	104.4	125.6	151.1
			Total,	**4650**	—	**3551.7**	—	**292.1**	**154.3**	**209.4**
6*a*	Dis. Bn-bl'k, Mixed	320	Grain,	850	82.6	702.1	8.3	44.3	*	*
	Mur. of Pot., Mn'ls,	160	Stover,	1575	61.2	963.9	5.2	50.1	*	*
			Total,	**2425**	—	**1666.0**	—	**94.4**	*	*
10	Mixed Min's, as No. 6*a*,	480	Grain,	1600	81.9	1310.4	8.2	107.5	139.4	152.7
	Sul. of Am. (25 lbs. N.),	120	Stover,	2850	50.2	1430.7	5.6	80.1	104.9	115.9
			Total,	**4450**	—	**2741.1**	—	**187.6**	**119.1**	**134.5**
11	Mixed Min's, as No. 6*a*,	480	Grain,	2500	87.7	2192.5	10.1	221.4	233.3	314.5
	Sul. of Am. (50 lbs. N.),	240	Stover,	3300	56.9	1877.7	6.5	122.1	137.8	176.7
			Total,	**5800**	—	**4070.2**	—	**343.5**	**176.8**	**246.3**
12	Mixed Min's, as No. 6*a*,	480	Grain,	2700	79.5	2146.5	9.3	199.6	228.4	283.5
	Sul. of Am. (75 lbs. N.),	360	Stover,	3600	65.7	2365.2	6.3	149.0	173.6	215.6
			Total,	**6300**	—	**4511.7**	—	**348.6**	**196.0**	**249.9**
00	Nothing, - - -	—	Grain,	525	84.1	441.5	10.0	44.2	47.0	62.8
			Stover,	750	76.8	576.0	9.4	54.1	42.3	78.4
			Total,	**1275**	—	**1017.5**	—	**98.3**	**44.2**	**70.5**
6*b*	Mixed Min's, as No. 6*a*,	480	Grain,	1450	81.2	1177.4	8.2	96.5	*	*
			Stover,	2450	71.9	1761.6	5.0	88.1	*	*
			Total,	**3900**	—	**2939.0**	—	**184.6**	*	*

* The average of the yields on plots 6*a* and 6*b* is here taken as 100 for comparison.

TABLE 69.

SPECIAL NITROGEN EXPERIMENTS ON WHITE FLINT CORN (SERIES F).

Percentages and pounds per acre of dry matter and of protein in the grain and stover.

No. of plot.	Fertilizers per Acre. Kind.	Weight.	Portion of crop.	Weight at harvest per acre.	Dry matter.		Protein in dry matter. N. × 6.25		Percentage of yield on basis of yield from mineral plots. Dry matter.	Percentage of yield on basis of yield from mineral plots. Protein.
		Lbs.		Lbs.	%	Lbs.	%	Lbs.	%	%
0	Nothing, - - -	—	Grain,	100	86.1	86.1	9.5	8.2	15.0	15.7
			Stover,	650	68.6	445.9	6.1	27.2	37.1	45.3
			Total,	**750**	—	**532.0**	—	**35.4**	**30.0**	**31.5**
7	Mixed Min's, as No. 6*a*,	480	Grain,	500	85.1	425.5	9.5	40.4	74.2	77.2
	Nit. of Soda (25 lbs. N.),	160	Stover,	1725	63.8	1100.6	4.6	50.6	91.5	84.2
			Total,	**2225**	—	**1526.1**	—	**91.0**	**86.0**	**81.0**
8	Mixed Min's, as No. 6*a*,	480	Grain,	1350	83.8	1131.3	9.5	107.5	197.3	205.5
	Nit. of Soda (50 lbs. N.),	520	Stover,	1875	76.1	1426.9	4.6	65.6	118.7	109.2
			Total,	**3225**	—	**2558.2**	—	**173.1**	**144.1**	**154.1**
9	Mixed Min's, as No. 6*a*,	480	Grain,	2000	83.9	1678.0	9.8	164.4	292.7	314.3
	Nit. of Soda (75 lbs. N.),	480	Stover,	1775	74.7	1325.9	5.6	74.3	110.3	123.6
			Total,	**3775**	—	**3003.9**	—	**238.7**	**169.2**	**212.6**
6*a*	Dis. Bn-bl'k, Mixed	320	Grain,	625	82.4	515.0	9.5	48.9	*	*
	Mur. of Pot. Min'ls,	160	Stover,	1850	65.0	1202.5	5.0	60.1	*	*
			Total,	**2475**	—	**1717.5**	—	**109.0**	*	*
10	Mixed Min's, as No. 6*a*,	480	Grain,	1600	82.5	1320.0	9.2	121.4	230.2	232.1
	Sul. of Am. (25 lbs. N.),	120	Stover,	2500	64.9	1622.5	4.8	77.9	134.9	129.6
			Total,	**4100**	—	**2942.5**	—	**199.3**	**165.8**	**177.5**
11	Mixed Min's, as No. 6*a*,	480	Grain,	2000	80.7	1614.0	9.2	77.9	281.5	148.9
	Sul. of Am. (50 lbs. N.),	240	Stover,	2275	62.3	1417.3	6.8	96.4	117.8	160.4
			Total,	**4275**	—	**3031.3**	—	**174.3**	**170.8**	**155.2**
12	Mixed Min's, as No. 6*a*,	480	Grain,	1100	81.8	899.8	9.9	89.1	155.2	170.4
	Sul. of Am. (75 lbs. N.),	360	Stover,	1075	73.7	792.3	9.3	73.7	65.9	122.6
			Total,	**2175**	—	**1692.1**	—	**162.8**	**95.3**	**145.0**
00	Nothing, - - -	—	Grain,	400	85.6	342.4	8.8	30.1	59.7	57.6
			Stover,	850	71.4	606.9	8.3	50.4	50.5	83.9
			Total,	**1250**	—	**949.3**	—	**80.5**	**53.5**	**71.7**
6*b*	Mixed Min's, as No. 6*a*,	480	Grain,	750	84.2	631.5	8.8	55.6	*	*
			Stover,	2000	60.1	1202.0	5.0	60.1	*	*
			Total,	**2750**	—	**1833.5**	—	**115.7**	*	*

* The average of the yields on plots 6*a* and 6*b* is here taken as 100 for comparison.

the fact that the crop on these plots never reached full maturity, owing to a lack of available plant food. Under such conditions the percentages of nitrogen are usually higher. This has been explained in previous reports* and need not be enlarged upon here.

With one exception the percentages of protein in the crops from the sections of the mineral plots were lower than in the crops from sections of the plots supplied with nitrogen. For this reason, and because the yields of crop were small, the total yields of protein on the sections supplied with only mineral fertilizers were light. The averages of the yields of dry matter and of protein obtained on these sections are used as a basis in discussing the yields on plots supplied with nitrogen.

It will be noticed that in the majority of cases the percentages of protein in the crop on sections supplied with nitrogen were higher than in the crop from areas where the minerals only were applied; the percentages of protein, however, in many cases did not correspond with the quantities of nitrogen used as fertilizer; in other words, there was not a regular increase in protein as the nitrogen was increased. The irregularities in this respect were much more noticeable than in some seasons in the past. For example, in the experiment on this field in 1900 the percentages of protein were increased correspondingly with the amounts of nitrogen used as fertilizer in every case except where the largest amounts of nitrogen in the form of sulphate of ammonia were used, and the irregularity in this case might perhaps be accounted for by abnormal conditions caused by an acidity of the soil. The irregularity in the percentages and yields of protein in the experiments of 1901 may have been caused by the unusually wet season. This condition was pointed out in the case of the yields of the crop, and it seems reasonable to assume that the percentages of protein might have been affected by the same condition.

By examining the relative yields in the last two columns in Tables 68 and 69 it will be noticed that in many cases on the sections supplied with nitrogen the yields of protein increased more rapidly than the yields of the dry matter. This points to the conclusion that the nitrogen in the fertilizer tends to

---

* See discussion of the results of analysis of "good" and "poor" corn, page 28, Report of this Station for 1890.

increase the proportion of protein relatively more than it does the yields of dry matter. The comparative yields show, too, the great advantage in using nitrogenous fertilizers for the purpose of increasing the feeding value of the crop. By their use both the yields of total crop and the proportions of nitrogen and of protein in the crop are increased.

EXPERIMENTS WITH COW PEAS.

By reference to the diagram on page 124 it may be seen that the two series of sections adjoining each other and designated as C and D were used for the experiments with cow peas. The results obtained on the corresponding sections have been combined and the data reported as if obtained from sections one twenty-fifth acre each. The Whippoorwill variety of cow peas was grown. As most varieties of this crop do not mature seed in this climate, new seed must be obtained each year from further south. The crop is harvested before or near the time of blossoming, and is used for fodder.

The amounts and cost of fertilizers per acre, the yields of crop per section as harvested and the calculated yields per acre, and the increase in yield on the fertilized plots over the average of the yields from the two plots where no fertilizer was used, are given in Table 70. The percentages and amounts of dry matter in the crop as harvested, and the percentages and amounts of protein in the dry matter, which are usually reported, are here omitted. Samples for analysis were taken as usual when the crop of 1901 was harvested, but because the heater for operating the large drier was not in order the samples could not be dried by heating; instead of this they were spread out thinly in a large room, but owing to continued wet weather they moulded seriously before they dried, so that it was deemed best not to analyse them.

The amounts of nitrogen in the fertilizer and the total yields of the crop.—From the results given in Table 70 it will be seen that the yields per acre as calculated from the data for the different sections are very irregular. On the whole, however, the indication is that the nitrogenous fertilizer had very little effect on the yields. The best yield of any section was obtained from one of the plots (6*b*) supplied with mineral fertilizers only, while the yield on the other mineral plot (6*a*) was equal

to the average of the yields on all the plots supplied with nitrogen in addition to the mineral fertilizers. The results this year, as in the past, point to the small value of nitrogen for this crop. In nearly all cases during an experience of twelve years in growing cow peas there has been but very little increase from the use of nitrogen when the mineral fertilizers were liberally supplied. The plowing under of cow peas for increasing the nitrogen in the soil is one very important use for the crop, but it should be remembered that on worn out soils liberal quantities of phosphates and potash should be used as fertilizer if a fair crop is to be obtained for this purpose.

TABLE 70.

SPECIAL NITROGEN EXPERIMENTS ON COW PEA FODDER.

Weight and cost of fertilizers per acre, total crop, and increase of crop over that of nothing plots.

No. of Plot.	Fertilizers per Acre. Kind.	Weight.	Cost.	Yield per section. (1-25 acre.)	Estimated yield per acre as harvested.		Gain over nothing plots.
		Lbs.	$	Lbs	Lbs.	Tons	Lbs.
0	Nothing,	—	—	400	10000	5.0	—
7	Mixed Minerals, as No. 6*a*, Nitrate of Soda (25 lbs. N.),	480 160	9.64	810	20250	10.1	12312
8	Mixed Minerals, as No. 6*a*, Nitrate of Soda (50 lbs. N.),	480 320	13.14	780	19500	9.8	11562
9	Mixed Minerals, as No. 6*a*, Nitrate of Soda (75 lbs. N.),	480 480	16.64	860	21500	10.8	13562
6*a*	Dis. Bone-black, Mur. of Potash, } Mixed Minerals,	320 160	6.14	810	20250	10.1	12312
10	Mixed Minerals, as No. 6*a*, Sulph. of Am. (25 lbs. N.),	480 120	10.27	840	21000	10.5	13062
11	Mixed Minerals, as No, 6*a*, Sulph. of Am. (50 lbs. N.),	480 240	14.39	765	19125	9.6	11187
12	Mixed Minerals, as No. 6*a*, Sulph. of Am. (75 lbs. N.),	480 360	18.52	780	19500	9.8	11562
00	Nothing,	—	—	235	5875	2.9	—
6*b*	Mixed Minerals, as No. 6*a*,	480	6.14	870	21750	10.9	13812

EXPERIMENTS WITH SOY BEANS.

The two series of sections designated as B and E in the diagram on page 124 were planted with soy beans. The results on the two series of sections have been combined, and are

reported as if obtained from sections one twenty-fifth acre each. The early white variety of soy beans has been regularly grown in this experiment since 1895. Only the seed has been taken into account in discussing the results with this crop, as most of the leaves drop off before the seed matures, leaving only the coarse stems as straw.

The amounts and cost of the fertilizer per acre, the yields of seed per section and the estimated yields per acre are shown in Table 71. The percentages and amounts of protein in the dry matter are shown in Table 72.

The amounts of the fertilizer and the total yields of the crop.— The results given in Table 71 indicate the effects of the nitrogen of the fertilizer on the yields of seed. The smallest yields were of course obtained on the sections without fertilizers. The yields on the sections supplied with mineral fertilizers were

TABLE 71.

SPECIAL NITROGEN EXPERIMENTS ON SOY BEAN SEED.

Weight and cost of fertilizers per acre, total crop, and increase of crop over that of the nothing plots.

No. of plot.	Fertilizers per Acre. Kind.	Weight.	Cost.	Yield per section. (1-25 acre.)	Estimated yield per acre.		Gain over nothing plots.
		Lbs.	$	Lbs.	Lbs.	Bu.	Bu.
0	Nothing	—	—	23.0	575	9.6	—
7	Mixed Minerals, as No. 6*a*, Nitrate of Soda (25 lbs. N.),	480 160	9.64	41.0	1025	17.1	8.2
8	Mixed Minerals, as No. 6*a*, Nitrate of Soda (50 lbs. N.),	480 320	13.14	46.0	1150	19.2	10.3
9	Mixed Minerals, as No. 6*a*, Nitrate of Soda (75 lbs. N.),	480 480	16.64	45.0	1125	18.8	9.9
6*a*	Dis. Bone-Black, Mixed Mur. of Potash, Minerals,	320 160	6.14	32.0	800	13.3	4.4
10	Mixed Minerals, as No. 6*a*, Sulph. of Am. (25 lbs. N.),	480 120	10.27	38.0	950	15.8	6.9
11	Mixed Minerals, as No. 6*a*, Sulph. of Am. (50 lbs. N.),	480 240	14.39	35.0	875	14.6	5.7
12	Mixed Minerals, as No. 6*a*, Sulph. of Am. (75 lbs. N.),	480 360	18.52	31.0	775	12.9	4.0
00	Nothing,	—	—	19.5	488	8.1	—
6*b*	Mixed Minerals, as No. 6*a*,	480	6.14	35.0	875	14.6	5.7

quite light but were much larger than where no fertilizers were used. On the whole the yields were very irregular, a condition that has been pointed out in the discussion of the results obtained with other crops, and which was probably due to the wet season. The series of sections supplied with nitrate of soda (plots 7, 8 and 9) gave considerably larger yields than were obtained on the sections supplied with mineral fertilizers only; there was no relation, however, between yields obtained and amounts of nitrogen supplied. It is of interest to note that the increase of yields resulting from the use of sulphate of ammonia was smaller than that from nitrate of soda, and that the yields decreased in quantity with the increase of sulphate used. This condition was not noticed in the experiment of 1900, but it may perhaps be due this year to an increasing acidity of the soil (as pointed out in the the corn experiments) resulting from the residue of acid left in the soil where large quantities of sulphate of ammonia were used.

The amounts of nitrogen in the fertilizer and the total yields of the crop.—The effects of the nitrogen in the fertilizer on the percentages and yields of dry matter and of protein are indicated by the results in Table 72. As was the case in the corn experiments, the highest percentages of protein in the soy beans are from the crops on the section without fertilizers. This is probably due to the presence of a considerable proportion of immature or partially developed seed. The percentages of protein in the crop from the section supplied with only mineral fertilizer were lower than in the crop where nitrogen supplied in the form of nitrate of soda was used. This would seem to indicate that the nitrogen influenced in some degree the composition of the crop as regards protein. Where the sulphate of ammonia was used as fertilizer, however, the percentages were lower than on one of the mineral plots, and in some cases nearly as low as on the other. As was pointed out in the case of the yields of crop, the nitrogen from sulphate of ammonia seemed to have little effect on the composition of the crop. In fact the percentages of protein, like the yields of crop, are in inverse order to the amounts of sulphate of ammonia used. The relative effects of nitrogen on the yields per acre of dry matter and of protein may be seen by referring to the

last two columns of Table 72. The small benefit derived from nitrogenous fertilizers is in striking contrast to the results obtained with corn, as may be seen by comparing these figures with those in corresponding columns of Table 68.

TABLE 72.

SPECIAL NITROGEN EXPERIMENTS ON SOY BEAN SEED.

Percentages and pounds per acre of dry matter and of protein.

No. of plot.	Fertilizers per Acre. Kind.	Fertilizers per Acre. Weight.	Weight at harvest per acre.	Dry matter.		Protein in dry matter. N. × 6.25.		Per cent. of yield on basis of yield from min'r'l plots. Dry matter.	Per cent. of yield on basis of yield from min'r'l plots. Protein
		Lbs.	Lbs.	%	Lbs.	%	Lbs.	%	%
0	Nothing, - , -	—	575	90.9	522.7	44.7	233.6	68.7	76.0
7	Mixed Min'ls, as No. 6*a*, Nit. of Soda (25 lbs. N.),	480 160	1025	90.2	924.6	42.3	391.1	121.5	127.2
8	Mixed Min'ls, as No. 6*a*, Nit. of Soda (50 lbs. N.),	480 320	1150	90.4	1039.6	43.8	455.3	136.5	148.1
9	Mixed Min'ls, as No. 6*a*, Nit. of Soda (75 lbs. N.),	480 480	1125	90.7	1020.4	44.1	450.0	134.1	146.4
6*a*	Dis. Bn-bl'k, } Mixed Mur. of Pot., } Min'ls,	320 160	800	90.3	722.4	41.6	300.5	*	*
10	Mixed Min'ls, as No. 6*a*, Sul. of Am. (25 lbs. N.),	480 120	950	91.4	868.3	40.3	349.9	114.1	113.8
11	Mixed Min'ls, as No. 6*a*, Sul. of Am. (50 lbs. N.),	480 240	875	91.9	804.1	40.1	322.4	105.6	104.9
12	Mixed Min'ls, as No. 6*a*, Sul. of Am. (75 lbs. N.),	480 360	775	90.5	701.4	39.6	277.8	92.2	90.4
00	Nothing, - - -	—	488	92.0	449.0	45.9	206.1	59.0	67.1
6*b*	Mixed Min'ls, as No. 6*a*,	480	875	91.4	799.8	39.3	314.3	*	*

*The average of the yields on plots 6*a* and 6*b* is here taken as 100 for comparison.

SOIL TEST WITH SOY BEANS.

The soil test of 1901 is the twelfth in a series that was begun in 1890 and has been continued year by year upon the same plots, but with a four year rotation of crops, namely, corn, potatoes, oats and either cow peas or soy beans. The purpose of the experiment is to study the deficiencies of the soil and the demands of different crops for the different ingredients of fertilizers. The general plan consists in dividing a field into parallel plots, applying on the different plots fertilizers which will supply nitrogen, phosphoric acid and potash singly and in different combinations, and growing the same crop on all the plots. The kinds and amounts of fertilizers per acre are nitrate

of soda 160 pounds, equivalent to 25 pounds of nitrogen; dissolved bone-black 320 pounds, equivalent to 53 pounds of phosphoric acid; muriate of potash 160 pounds, equivalent to 82 pounds of potash. These are applied singly, two by two, and all three together, thus making seven different kinds of fertilizers, the combination of the three being a so-called "complete" fertilizer. On an eighth plot a moderate quantity of stable manure with some phosphoric acid in addition was applied, and on a ninth a liberal quantity of stable manure alone. Three other plots in the group are left unmanured.

Diagram illustrating the arrangement of the plots in the soil test, and the kinds of fertilizers and amounts per acre used on each plot.

Unfertilized strips separate the adjoining plots.

EAST.

NORTH. | SOUTH.

PLOT 0. Nothing.	PLOT Y. Stable manure, 16000 lbs.
PLOT A. Nit. of Soda, 160 lbs.	PLOT X. Stable man., 10000 lbs.; Dis. Bone-bl'k, 160 lbs.
PLOT B. Dis. Bn-bl'k, 320 lbs.	PLOT 000. Nothing.
PLOT C. Mur. of Pot., 160 lbs.	PLOT G. Dis. Bone-bl'k, 320 lbs.; Mur. of Pot., 160 lbs.; Nit. of Soda, 160 lbs.
PLOT 00. Nothing.	PLOT F. Dis. Bone-bl'k, 320 lbs.; Mur. of Pot., 160 lbs.
PLOT D. Dis. Bn-bl'k, 320 lbs.; Nit. of Soda, 160 lbs.	PLOT E. Mur. of Pot., 160 lbs.; Nit. of Soda, 160 lbs.
PLOT E. Mur. of Pot., 160 lbs.; Nit. of Soda, 160 lbs.	PLOT D. Dis. Bn-bl'k, 320 lbs.; Nit. of Soda, 160 lbs.
PLOT F. Dis. Bn-bl'k, 320 lbs.; Mur. of Pot., 160 lbs.	PLOT 00. Nothing.
PLOT G. Dis. Bn-bl'k, 320 lbs.; Mur. of Pot., 160 lbs.; Nit. of Soda, 160 lbs.	PLOT C. Mur. of Pot., 160 lbs.
PLOT 000. Nothing.	PLOT B. Dis. Bone-bl'k, 320 lbs.
PLOT X. Stable man., 1000 lbs.; Dis. Bn-bl'k, 160 lbs.	PLOT A. Nit. of Soda, 160 lbs.
PLOT Y. Stable man., 16000 lbs.	PLOT 0. Nothing.

WEST.

The diagram above will illustrate the method of laying out the field, and the kinds and amounts of fertilizers per acre applied on each plot. The soil of the experimental field is a medium loam with a yellow clay subsoil, and has good natural drainage. The field slopes slightly to the south, and the plots are laid out with the long dimension corresponding to the slope, in order to prevent the washing of soil from one plot to another. The soil has not washed seriously, although very heavy rains have caused some washing of the surface. In 1889, before the experiment was begun, it was noticed that one side of the field was more fertile than the other, and to overcome, as far as possible, the effect of this irregularity it was thought best to lay out the field in two halves, the order of the plots on these to be reversed. In this way 24 one-twenty-fourth acre plots were laid out, as shown in the diagram of the field. In harvesting the crop the yields on the corresponding plots of the two sets are combined and are reported on the basis of one-twelfth acre plots.

Experiment with soy beans in 1901.—The medium early green soy bean was the crop grown in 1901. The data of the experiment are given in Table 73, only the seed being taken into account.

The yields on the various plots without fertilizers were nearly the same, indicating that the fertility of the soil is fairly uniform. Where the three ingredients, nitrogen, phosphoric acid and potash, were used separately (plots A, B and C) the nitrate of soda plot (A) gave slightly the best yield. The results from the use of the combinations of nitrogen and phosphoric acid, nitrogen and potash, and phosphoric acid and potash, would seem to show that the phosphoric acid was equally as important as nitrogen on this soil. Where all three of the fertilizers were applied (plot G) there was very little increase in yield over that obtained where only mineral fertilizers were used (plot F). The results on the whole would seem to suggest that while the nitrogen was possibly of some value to soy beans it should be used more sparingly than for most crops, and especially more so than for the cereals or grasses.

It is interesting to notice that the yields obtained where stable manure was used were quite a little larger than from the plot supplied with a complete chemical fertilizer (G). This

TABLE 73.

SOIL TEST WITH FERTILIZERS ON SOY BEANS.

BY THE STATION, STORRS, 1901.

No. of plot.	Fertilizers per Acre. Kind.	Weight.	Cost.	Yield per plot. 1-12 acre.	Yield per acre.		Gain over nothing plots.
		Lbs.	$	Lbs	Lbs.	Bu.	Bu.
0	Nothing,	—	—	109	1308	21.8	—
A	Nitrate of Soda,	160	3.50	122	1464	24.4	4.1
B	Dis. Bone-black,	320	2.65	116	1392	23.2	2.9
C	Muriate of Potash,	160	3.49	107	1284	21.4	1.1
00	Nothing,	—	—	93	1116	18.6	—
D	Nitrate of Soda, Dis. Bone-black,	160 320	6.15	132	1584	26.4	6.1
E	Nitrate of Soda, Muriate of Potash,	160 160	6.99	120	1440	24.0	3.7
F	Dis. Bone-black, Muriate of Potash,	320 160	6.14	133	1596	26.6	6.3
G	Nitrate of Soda, Dis. Bone-black, Muriate of Potash,	160 320 160	9.64	142	1704	28.4	8.1
000	Nothing,	—	—	103	1236	20.6	—
X	Stable manure, Dis. Bone-black,	†10000 160	7.99	175	2100	35.0	14.7
Y	Stable manure,	‡16000	10.68	177	2124	35.4	15.1

may have been due in part to the wet season, which would have favored the leaching away of the nitrates where the nitrate of soda was used, while the slower acting organic nitrogen in the form of manure would have been made available gradually throughout the season. Probably, also, the soil on plot G, on which only the chemical fertilizers have been applied for so many years, is lacking in beneficial organic matters (humus, etc.), which would be present in the soil on which the stable manure was used.

Average yields of crops grown in soil tests.—By repeating the rotation in this experiment through a series of years the inequalities of season are partially eliminated; thus the results would naturally be expected to be of increasing value as time goes on. The average results in yields of crops are shown in the following table.

TABLE 74.

Average yield per acre in Station soil test during twelve years.

No. of Plot.	Fertilizers. Kind.	Weight per acre.	Corn. Avg. for 3 years. 1890, 1894, 1898.	Potatoes. Avg. for 3 years. 1891, 1895, 1899.	Oats (seed). Avg. for 3 years. 1892, 1896, 1900.	Cow peas (vines). 1893.	White soy beans (seeds). 1897.	Green soy beans (seeds). 1901.
		Lbs.	Bu.	Bu.	Bu.	Lbs.	Bu.	Bu.
0	Nothing,	—	28.7	66.0	27.1	10230	6.8	21.8
A	Nitrate of Soda,	160	33.6	61.4	34.6	10960	6.2	24.4
B	Dis. Bone-black,	320	32.8	64.3	32.5	10710	7.1	23.2
C	Muriate of Potash,	160	30.9	108.1	26.8	11680	6.4	21.4
00	Nothing,	—	23.8	50.3	24.3	9725	7.1	18.6
D	Nitrate of Soda, Dis. Bone-black,	160 320	36.8	67.5	40.9	12920	9.0	26.4
E	Nitrate of Soda, Muriate of Potash,	160 160	36.7	119.8	35.6	13335	7.6	24.0
F	Dis. Bone-black, Muriate of Potash,	320 160	35.5	139.8	30.7	1579	9.3	26.6
G	Nitrate of Soda, Dis. Bone-black, Muriate of Potash,	160 320 160	43.7	170.1	42.2	16210	8.6	28.4
000	Nothing,	—	28.5	55.1	24.7	12100	7.7	20.6
X	Stable manure, Dis. Bone-black,	10000 160	47.1	136.1	43.3	15795	11.5	35.0
Y	Stable manure,	16000	47.8	165.6	48.4	15875	12.7	35.4

While some slight differences are shown as to the peculiar needs of crops, the soil as a whole seems to be lacking in all three of the essential fertilizer ingredients. The following conclusions as to the needs of particular crops seem warranted. Oats have shown marked increase in yield from the use of nitrogen and phosphoric acid, while corn has seemed to need all the ingredients applied in the fertilizers. Potatoes, on the other hand, have been most benefited by applications of potash. Thus the special needs of different crops are to some extent indicated by these tests. They can only be told with certainty, however, by long experimenting, under similar conditions.

SUMMARY AND GENERAL DEDUCTIONS.

The special nitrogen experiments here reported were made with corn, cow peas, and soy beans. The purpose of the experiments is twofold: first, to study the effects upon the yields of the crops when different kinds and quantities of nitrogenous fertilizers are used in addition to uniform quantities of mineral fertilizers; and second, to study the effect of the nitrogen in the fertilizers upon the percentage and amount of protein in the crops.

The experiments with corn indicate that while the mineral fertilizers were very essential to the corn crop, they were not sufficient for this crop or this soil when used alone. A complete fertilizer with nitrogen, phosphoric acid and potash was essential for good yields of corn. When the yields alone are considered, the most profitable results financially have been obtained with 25 to 50 pounds of nitrogen per acre (in nitrate of soda) used in connection with mineral fertilizers. When the feeding value of the crop is considered even larger quantities of nitrogen than 50 pounds per acre seem to give profitable returns. While the yields of dry matter have not generally been much increased by an increase of nitrogen beyond 50 pounds per acre, the percentages of nitrogen and of protein in both the grain and the stover have been highest in the crops where the largest quantities of nitrogen have been used in the fertilizers.

The experiments with legumes—cow peas and soy beans—indicate that mineral fertilizers are of great value in increasing the yields of these crops, while nitrogenous fertilizers do not greatly increase either the yield or the percentage of protein in the crop over that obtained from the mineral fertilizers only. In the experiments thus far made by the Station the average results with cow pea fodder show practically no advantage from the use of nitrogenous fertilizers. In the experiments with soy beans grown for seed some increase seems to have resulted from the use of nitrogenous fertilizers, although that increase was small. The percentages and yields of protein in these legumes bore very little relation to the quantities of nitrogen used, the protein being increased but little if any by the use of nitrogenous fertilizers.

The results of the soil test of 1901 indicate that the mineral fertilizers were of greater value than nitrogen in increasing the yields of soy beans. Nitrogen was of some value, however, especially when supplied in the form of manure. While the complete fertilizer (plot G) gave an increase of only two bushels per acre over the yield where only mineral fertilizers were used (plot F), the manure (plots X and Y) gave an increase of nearly nine bushels.

In general the results obtained during the past twelve years with the leading crops indicate that nitrogen and phosphoric acid are of prime importance for use on this particular soil in order to get good yields of oats. The same ingredients also produced the most marked results on the yields of corn during the three years in which this crop has been grown in the rotation, while on the other hand, potatoes have responded more generally to the use of potash.

AN EXPERIMENT ON SOIL IMPROVEMENT.

BY C. S. PHELPS.

In 1899 the Station began an experiment on a series of plots of land at Storrs, the purpose of which was to compare the value and economy of different methods of manuring for restoring the fertility to a soil such as is commonly described as "poor" or "worn out." This experiment was to be continued through a period of several years on the same plots. The results here reported are those for the third consecutive year.

The soil of the field on which this experiment is conducted is medium heavy loam which holds moisture well, but apparently is lacking in organic material and probably in available nitrogen. The field had been used for a peach orchard from 1889 to 1898, and while the peach trees were growing it had been treated liberally with the mineral fertilizers, phosphoric acid and potash, but little or no nitrogen had been applied. During the years 1889–1894 different crops were grown between the rows of trees and were removed from the land; after 1894 the soil was kept under cultivation but no crops were grown except the peaches. Part of the peach trees were removed in the fall of 1897 and the remainder in the fall of 1898. In the spring of 1899 a series of parallel plots was laid out upon the field for the purpose of the present experiments.

The plan of these experiments consists in treating the different plots with different kinds of fertilizers in such a way as to "build up" the general fertility of the soil, growing the same crop on all the plots, and estimating the relative value of the different methods of manuring by a comparison of the results from the different plots. The kinds of fertilizers used are (1) stable manure, (2) a "complete" chemical fertilizer, and (3) "green" manures, both alone and in combination with mineral fertilizers. The following crops are grown in the experiment in a four-year rotation: Corn, potatoes, oats and peas for

fodder, and soy beans. The arrangement of the plots and the method of fertilizing each plot are shown in the diagram below.

Arrangement of plots and method of fertilizing in experiment on soil improvement, 1901.

Plot K. "Complete" fertilizer, 800 lbs. per acre.

Plot L. Stable manure, 8 tons (3.4 cords) per acre.

Plot M. Clover or other legume for green manuring.

Plot N. Mineral fertilizers, 700 lbs. per acre, and rye for green manuring.

Plot P. Mineral fertilizers, 700 lbs. per acre, and clover or other legume for green manuring.

The plots contain one-eighth acre each, and are separated by strips 3.3 feet wide. These strips between the plots and similar strips at the ends and sides of the field are planted the same as the plots, but no fertilizer is applied on them and the growth on the strips is harvested before that on the plots and not included in the experiment.

The piece of land on which these plots are laid out is contiguous to that used for the special nitrogen and soil test experiments. The slope on this field is even greater than that on the others, and the inaccuracies due to washing of the soil by rains may be greater. It is believed, however, that they have not interfered very seriously with the results of this experiment.

Plot K is supplied with a liberal amount of complete chemical fertilizer, and plot L with a liberal amount of mixed stable manure. It is intended that the pecuniary value of the fertilizer used on plot K shall be approximately the same as that of the stable manure on plot L, estimating the fertilizer according to the system of valuation followed by the New England Experiment Stations, and valuing the manure at $3 per

cord. The complete chemical fertilizer on plot K was applied in 1899 and 1900 at the rate of 1,200 pounds per acre, the materials included in the fertilizer being mixed in the following proportions: Nitrate of soda 200 pounds, sulphate of ammonia 100 pounds, tankage 200 pounds, muriate of potash 200 pounds, South Carolina acid phosphate 500 pounds. In 1901 the fertilizers were mixed in the same proportions as above but only 800 pounds per acre were applied. On plot L 12 tons, or 5⅓ cords, of stable manure per acre were applied in 1899 and 1900; in 1901 the quantity was reduced to 8 tons or 3.4 cords per acre.

Plot M receives no fertilizer, but whenever practicable some leguminous crop is grown on the plot between the seasons of the regular crops, from year to year, for the purpose of plowing under. Clover was grown after the corn crop of 1899 and was plowed under in the spring of 1900. Winter vetch was sown in September, 1900, after the potatoes were harvested; this made a thin growth and was only 3 to 4 inches high when winter came, and a considerable amount of it was killed during the winter. There was, therefore, only a light growth of vetch to plow under in May, 1901, in connection with the experiment here reported.

On plots N and P a mixture of South Carolina acid phosphate and muriate of potash is applied at the rate of 700 pounds per acre, the proportion being 500 pounds of the former to 200 pounds of the latter. In addition to this, green crops grown between the seasons of the regular crops are also plowed under. Rye was grown on plot N after the corn crop of 1899 and was plowed under before the regular crop of 1900 was planted. Rye was sown again after the potato crop of 1900 was harvested, and the growth was plowed under in May 1901 before the experiment of that year. On the plot P clover was grown after the corn crop of 1889 and plowed under in the spring of 1900. Winter vetch was sown in September 1900 after the potatoes were harvested and was plowed under in May 1901, but as in the case of plot M there was only a light growth of vetch in the fall and much of it was killed during the winter, so that there was but little to plow under.

In conducting the experiment on soil improvement according to the plan outlined there has been some difficulty in selecting crops that would give satisfactory returns in green manure because of the conditions under which they may be grown in the experiment. Good crops of rye have been obtained each year on plot N. There was a fair growth of alsike clover on plots M and P to plow under in the spring of 1900, but this had been sown in the latter part of July, 1899, amongst the corn after it was cultivated for the last time. Since the potatoes grown in the experiment of 1900 were rather late in maturing, and as clover could not be sown to advantage before digging the tubers, it was thought best to try winter vetch as a catch crop on these plots between the seasons of 1900 and 1901, but as already explained, this crop made but little growth and the very little quantity that could be plowed under somewhat modified the yields of oats and peas on these plots during the experiments of 1901. Following the oats and peas, common red clover was sown early in August, 1901. On the whole, this crop gives the best promise of any yet tried for green manuring on this field, but in order to grow a crop of clover or other legume following the regular crop of the experiment and get a sufficient amount to plow under it is necessary either to sow the clover in the growing crop late in July or early in August, or to plant in the regular rotation only those crops which may be harvested early in the season and thus allow the clover to be sown on the cleared field not later than August.

Yields of oat and pea hay in 1901.—The yields of oat and pea hay from the different plots in the experiment of 1901 are given in the following table.

There was not a very heavy growth on any of the plots, the heaviest yield being that from plot K with the complete fertilizer, as has also been the case each year of the experiment thus far. As the field slopes considerably from plot P to plot K there may be more moisture in the soil of the latter plot and possibly some of the fertilizers from the soil of the other plots may be washed upon it, which would probably benefit the growth of the crop on plot K. However, from a comparison of the costs of the fertilizers used on the two plots as well as of the yields produced there does not appear to have been any

material advantage in the conditions of plot K over those of plot L; the cost of the fertilizer on plot L was only 81 per cent., while the yield of crop was 85 per cent. of that of plot K.

TABLE 75.

Yields of oats and peas in the experiment on soil improvement, 1901.

No. of plot.	Fertilizers per Acre. Kind.	Weight.	Cost.	Yield per plot, (1/8 acre) field cured.	Yield per acre field cured.
		Lbs.	$	Lbs.	Lbs.
K	Complete fertilizer, - - - - - -	800	12.00	715	5720
L	Stable manure, - - - - - - -	16000	10.26	610	4880
M	No fertilizer except vetch, - - -	—	—	495	3960
N	Mineral fertilizers and rye, - - -	700	7.59	475	3800
P	Mineral fertilizers and vetch, - - -	700	7.59	490	3920

The only expense for the green manuring of plots M, N and P was the cost of the seed and the time and labor of sowing it. The land was not plowed, as the soil was quite loose after the potatoes were dug; the seed was covered by harrowing the soil. No account was taken of the cost of seed and of labor. The cost of fertilizing plot M is therefore given in the table as nothing because the only fertilizer was the vetch for green manuring; and the cost of fertilizing plots M and P is given as that of the mineral fertilizers used, at the rate of $7.59 per acre on each plot.

Apparently the most economical of the methods of fertilizing these three plots was that on plot M. The yield from this plot, with no fertilizer but the vetch plowed under, was practically the same as that from plot P with mineral fertilizers in addition to the vetch, and was larger than that from plot N with the mineral fertilizers and rye for green manure. These results would indicate that the mineral fertilizers were of little or no advantage in this experiment and also that considerable benefit was derived from the vetch as manure, even though the crop plowed under was very light.

GENERAL SUMMARY AND CONCLUSIONS.

The experiment on soil improvement in 1900 was with potatoes and that of 1901 with oat and pea hay. In both years the yield was largest on the plot with the complete fertilizer, but in proportion to the cost of fertilizing the two plots the yield on the plot with the stable manure was fully as economically produced. In 1900 the yield from the plot with clover for manure was next in size to that from the plot with the complete fertilizer, and the yield from the plot with the minerals and clover for fertilizer was practically the same as that from the stable manure. In 1901 the yields of oat and pea hay where a light growth of vetch was plowed under, either alone or in combination with the mineral fertilizers, were much smaller than those where stable manure was used. In both years the yield on the plot where rye was plowed under in addition to the minerals was less than those from the plots on either side where the legumes were used. The results of both years indicate a considerable advantage in the use of legumes for green manure. On the whole, common red clover seems to be the best crop for the purpose of green manuring when it must be grown between the regular crops of a rotation as in the experiment here described. The experiment would need to be continued for several years before the results would warrant any reliable conclusions regarding the relative economy of the various methods of fertilizing for improving the fertility of the soil.

POT EXPERIMENTS WITH NITROGENOUS FERTILIZERS IN 1901.

BY C. S. PHELPS.

The chief difficulties met with in field experiments with fertilizers are variations in the soil of the different plots, irregularities of season, particularly in the amounts of rainfall, and the impossibility of applying fertilizers in such ways that the plants shall get the full benefit of them and at the same time not get plant food in varying quantities from other sources. In order to overcome these difficulties as far as possible, and to verify the results of the field experiments by investigations in which the conditions influencing the growth of the crops might be more under control, the Station for several years has carried on experiments in which plants were grown in a prepared soil in pots in a special vegetation house. In these experiments all the pots are filled from a lot of soil that has been very thoroughly mixed and is therefore quite uniform; the plants are all watered artificially so that the amount of moisture in the soil can be kept within certain limits; and the fertilizers are applied in such ways that there is little, if any, chance for loss of plant food.

A detailed account of these experiments, describing the pots and soil used, the method of applying the fertilizer and the water, the shelter house and the care of the plants during the growing season, the sampling and analyzing of the crops, etc., and giving the results obtained during several years with different crops, is given in the Report of the Station for 1900. In the present article, which reports the results of the experiment for 1901, these details are briefly recapitulated, and any variations in the methods of conducting the experiments are included.

Shelter house and pots.—The plant shelter is a light frame structure with a large number of windows. It has a gravel floor on a level with a yard at the west side and is fitted with

tracks which extend into the yard. On these tracks are placed trucks for holding the pots of soil in which the plants are grown. The pots used are 18.5 inches deep and 10 inches in diameter and will hold from 60 to 80 pounds of soil, sand and gravel. The pots are made of heavy galvanized iron and are fitted with half-inch lead pipes on the outside which are attached in such a way as to allow for watering at the bottoms of the pots.

The soil used and the method of filling the pots.—The soil used in the experiments was taken from field plots which have been supplied with nothing but mineral fertilizers since 1890. This soil was used because there seemed to be but little organic matter in it, and judging from the crops grown on it in recent years there was but little available nitrogen present. The soil was thoroughly mixed before it was put into the pots. In filling the pots about two inches of coarse gravel was placed in the bottom of each, and this was covered with a thin layer of sand; the soil was then added in layers of about one inch in thickness, each layer being well tamped as it was filled in. In the earlier experiments from 50 to 60 pounds of soil were used in each pot, the quantity varying somewhat for the different series, but uniform for each pot in the same series.

In the experiments of 1901 all of the soil which had been used in the experiments of 1900 was discarded and a new lot was obtained, as in previous years, from the mineral plots in the field experiments. This was placed in a heap and thoroughly mixed; the gravel and sand was placed in the bottom of each pot, and then 55 pounds of the mixed soil was added. The moisture content of the soil was determined by drying samples at 105° C.; the soil in pots 1 to 12 contained 13.25 per cent. and that in the other pots 12 per cent. The weights of the filled pots was ascertained, to be used as explained later in keeping the percentage of moisture of the soil within a certain range.

Adding the fertilizer.—To each pot in the whole experiment mineral fertilizers were applied uniformly as follows: phosphate of potash 2.54 grams, sulphate of potash .50 gram, carbonate of lime 4.00 grams. Some of the pots received no other fertilizer besides the minerals, while other pots received nitrate of

soda in addition, the quantity varying so as to furnish what have been designated as the one-third, the two-third and the full ration of nitrogen. The nitrate of soda used in the pots numbered 1 to 12 inclusive contained 16.24 per cent. of nitrogen and the quantities used were 2.05 grams for the one-third, 4.10 grams for the two-thirds, and 6.15 grams for the full ration; while that in pots numbered 17 to 64 contained 16.47 per cent. of nitrogen, and the quantities used were 2.025 grams, 4.050 grams and 6.075 grams, respectively. The amounts of the different fertilizing ingredients thus supplied were as follows:

TABLE 76.

	Nitrogen.	Phosphoric acid. (P_2O_5).	Potash. (K_2O).	Lime. (CaO).
	Gm.	Gm.	Gms.	Gms
Pots with minerals only,	0.00	1.0	1.5	2.2
Pots with minerals + ⅓ nitrogen ration,	.33⅓	1.0	1.5	2.2
Pots with minerals + ⅔ nitrogen ration,	.66⅔	1.0	1.5	2.2
Pots with minerals + full nitrogen ration,	1.00	1.0	1.5	2.2

In all the pots the mineral fertilizer was applied by mixing it with the soil before the crops were planted. About eight inches of soil from the top of that in each pot was removed, the fertilizer was thoroughly mixed with it and then it was replaced and tamped as before. In pots 1 to 12, which were used for growing grass from sod, the nitrogenous fertilizer also was added, to those pots which were to have nitrogen, at the same time as the minerals. In the other pots in which nitrogen was used the nitrate of soda was applied in solution, in some pots every day and in others every other day. Either 25 or 50 cubic centimeters of a weak solution of the nitrate was diluted to 500 cubic centimeters and then applied to the soil. In this way a definite amount of nitrate of soda was added every time the solution was used. The total amount thus added during the growing season was that given in the table above.

Care of the plants during the period of growth.—The pots in which the plants grew were placed upon trucks which rolled upon tracks and could be moved into and out of the plant shelter. At night, and during stormy weather, and when high winds would be likely to injure the plants, they were kept inside the shelter house; at other times they were out of doors. Care was taken to have the conditions of sunlight and moisture as nearly alike as possible for the plants in the different pots. The trucks on which the plants stood were switched from one track to another whenever necessary, so that the shorter plants would not be in the shade of the taller ones. The plants were kept under shelter during rainy weather, and water was supplied to them artificially, as often as seemed necessary to keep up a vigorous growth. The water used had previously been found by analysis to be practically free from nitrogen. Part of the water was applied at the bottom of the pot by means of the pipe entering from the outside, and part was poured upon the surface, for the purpose of distributing it through the soil. The water content of the soil was kept between 10 and 15 per cent. by weighing the pots with the soil and the growing plant and adding sufficient water to bring the total weight up to a given amount previously determined.

Sampling and analyzing the crops.—The total crop from each pot was used as a sample for analysis. The grasses and millets were cut one inch above the soil, and each sample was put into a loose paper bag and was dried in the air, and later was cut into pieces about one inch long and kept in sealed bottles or jars until analyzed. In the case of the soy beans only the seed from each pot was taken as a sample, no effort being made to save the straw because the leaves drop off before the seed is fully matured.

The only analysis of the crops was the determination of the percentage of total nitrogen in the samples. The data in the tables giving the results with the different crops include for each pot the amount of nitrogen in the fertilizer, the total weight of the crop, the percentage and weight of total nitrogen and the estimated percentage of total protein.

The amount of crop that can be grown in a pot in the experiments is so small that the results give little indication of the effect of the different quantities of nitrogenous fertilizers

upon the total yield of the crop. The particular importance of the results is the effect of the nitrogen of the fertilizer upon the percentage of nitrogen, and hence of protein in the crop. This is indicated by a comparison of the averages of the results from the pots with the different quantities of nitrogen, which are given in the last column of each table.

According to the usual custom, the percentage of protein is estimated by multiplying the percentage of nitrogen by the factor 6.25, on the assumption that all the nitrogen determined represents protein containing 16 per cent. of nitrogen. This involves at least two sources of error. The different forms of proteid vary in the proportions of nitrogen they contain, so that the factor that should be used may range between 5.8 and 6.4. Furthermore, a part of the nitrogen in the crop may be present not as protein but in the form of nitrates, which have no food value, yet any nitrogen that would come from them in the determination would be estimated as protein by this method. In the experiments here reported, however, the error due to nitrates would probably be inappreciable. In the experiments of 1900 the amounts of nitrogen in the fertilizer were much larger than those in 1901, but in tests for nitrates* in the crops of 1900 only very small quantities were found, and in only a part of the samples. The amount of nitrogen present in the form of nitrates in the crops of 1901 would therefore probably be negligible if there were any. In any case, the error due to the presence of the nitrates would be much less than that due to the use of wrong factors.

For practical purposes, however, the usual method of estimating protein is perhaps sufficiently accurate; and in order that the results of these experiments may be directly comparable with those previously reported, it seems best to follow the same method here that has been used before.

DISCUSSION OF THE EXPERIMENTS OF 1901.

The experiments of 1901 include one series of pots with meadow fescue grass, one with Hungarian grass, one with barnyard millet, and one with soy beans. Each experiment comprised four groups of pots; in the experiment with meadow

* Rept. Storrs Station 1900, p. 83.

fescue there were three pots in each group, in the other experiments there were four. One group in each series included the pots with mineral fertilizers only, one group with the one-third, one with the two-thirds, and one with the full nitrogen ration in addition to the minerals. The results from each group were averaged together. The details of the experiments and the discussion of the results follow.

EXPERIMENT WITH MEADOW FESCUE GRASS.

This experiment included pots Nos. 1 to 12. Three pots were used in each group, but the crop on one of the pots with mineral fertilizers was accidentally destroyed. The results of the experiment are given in Table 77.

TABLE 77.

Nitrogen in fertilizer and in crop in pot experiment with meadow fescue grass, 1901.

Lab. No.	Pot No.	Sample.	Fertilizer. Kind.	Fertilizer. Amount of nitrogen per pot.	Total weight crop.	Total nitrogen.		Protein. (N. × 6.25.)
				Gm.	G.	%	G.	%
6434	2	Meadow fescue,	Minerals only, - -	—	10	2.61	.26	16.31
6435	3	Meadow fescue,	Minerals only, - -	—	14	2.28	.32	14.25
		Average, -	—	—	**12**	**2.45**	**.29**	**15.28**
6436	4	Meadow fescue,	Minerals + ⅓ nit. ration,	.33⅓	13	2.41	.31	15.06
6437	5	Meadow fescue,	Minerals + ⅓ nit. ration,	.33⅓	15	2.41	.36	15.06
6438	6	Meadow fescue,	Minerals + ⅓ nit. ration,	.33⅓	13	2.48	.32	15.50
		Average, -	—	—	**14**	**2.43**	**.33**	**15.21**
6439	7	Meadow fescue,	Minerals + ⅔ nit. ration,	.66⅔	10	2.98	.30	18.63
6440	8	Meadow fescue,	Minerals + ⅔ nit. ration,	.66⅔	13	2.68	.35	16.75
6441	9	Meadow fescue,	Minerals + ⅔ nit. ration,	.66⅔	12	2.85	.34	17.81
		Average, -	—	—	**12**	**2.84**	**.33**	**17.73**
6442	10	Meadow fescue,	Min'ls + full nit. ration,	1.00	14	2.46	.34	15.37
6443	11	Meadow fescue,	Min'ls + full nit. ration,	1.00	14	2.62	.37	16.37
6444	12	Meadow fescue,	Min'ls + full nit. ration,	1.00	18	2.64	.48	16.50
		Average, -	—	—	**15**	**2.57**	**.40**	**16.08**

The growth on the different pots in the same group was fairly uniform, but for the different groups there was quite a wide variation both in the total amount of crop and in percentages of nitrogen in the crop. The increase in crop and in

percentages of nitrogen in the crop was not in direct proportion to the amount of nitrogen used in the fertilizer. The increase was much less regular in this experiment than in similar experiments with grasses in past years. It will be noticed, however, that the percentages of nitrogen and of protein in the crops were much higher where the higher rations of nitrogen were used as fertilizer than where the smaller amount or no nitrogen was applied. The growth as a whole was not quite as vigorous as in the experiments with Hungarian grass and with millet, nor as in some of the experiments with grasses in past years. This may account in part for the irregularities in the results obtained this year.

EXPERIMENT WITH HUNGARIAN GRASS.

The results of this experiment, which included pots 17 to 32, are given in Table 78.

TABLE 78.

Nitrogen in fertilizer and in crop in pot experiment with Hungarian grass, 1901.

Lab. No.	Pot No.	Sample.	Fertilizer. Kind.	Fertilizer. Amt. of nitrogen per pot.	Total weight crop.	Total nitrogen.		Protein. (N. × 6.25.)
				Gm.	G.	%	Gm	%
6445	17	Hungarian grass,	Minerals only, - -	—	28	1.14	.32	7.13
6446	18	Hungarian grass,	Minerals only, - -	—	30	1.12	.34	7.00
6447	19	Hungarian grass,	Minerals only, - -	—	28	1.07	.30	6.69
6448	20	Hungarian grass,	Minerals only, - -	—	32	1.17	.37	7.31
		Average, -	—	—	**30**	**1.13**	**.33**	**7.03**
6449	21	Hungarian grass,	Minerals + ⅓ nit. ration,	.33⅓	36	1.47	.53	9.19
6450	22	Hungarian grass,	Minerals + ⅓ nit. ration,	.33⅓	38	1.71	.65	10.69
6451	23	Hungarian grass,	Minerals + ⅓ nit. ration,	.33⅓	38	1.55	.59	9.69
6452	24	Hungarian grass,	Minerals + ⅓ nit. ration,	.33⅓	36	1.59	.57	9.94
		Average, -	—	—	**37**	**1.58**	**.59**	**9.88**
6453	25	Hungarian grass,	Minerals + ⅔ nit. ration,	.66⅔	36	2.16	.78	13.50
6454	26	Hungarian grass,	Minerals + ⅔ nit. ration,	.66⅔	36	2.18	.78	13.63
6455	27	Hungarian grass,	Minerals + ⅔ nit. ration,	.66⅔	39	2.07	.81	12.94
6456	28	Hungarian grass,	Minerals + ⅔ nit. ration,	.66⅔	36	2.07	.75	12.94
		Average, -	—	—	**37**	**2.12**	**.78**	**13.25**
6457	29	Hungarian grass,	Minerals + full nit. ration,	1.00	36	2.36	.85	14.75
6458	30	Hungarian grass,	Minerals + full nit. ration,	1.00	39	2.26	.88	14.12
6459	31	Hungarian grass,	Minerals + full nit. ration,	1.00	36	2.41	.87	15.06
6460	32	Hungarian grass,	Minerals + full nit. ration,	1.00	38	2.26	.86	14.12
		Average, -	—	—	**37**	**2.32**	**.86**	**14.51**

The average weight of the crop was the same on the pots with the different quantities of nitrogen, but was smaller on the pots with the mineral fertilizers alone. The percentages of protein in the crops increased steadily with the increase in the amount in the fertilizer, the average percentage in the crop with the full ration of nitrogen being more than twice that in the crop from the pots with no nitrogen. This is a striking illustration of the advantage of nitrogen as fertilizer for increasing the feeding value of such a crop as Hungarian grass.

EXPERIMENT WITH BARN YARD MILLET.

The experiment with barn yard or Japanese millet included pots 33 to 48. The results of the experiment are given in Table 79.

TABLE 79.

Nitrogen in fertilizer and in crop in pot experiment with barn yard millet, 1901.

Lab. No.	Pot No.	Sample.	Fertilizer. Kind.	Fertilizer. Amt. of nitrogen per pot.	Total weight crop.	Total nitrogen.		Protein. (N. × 6.25.)
				Gms.	G.	%	Gm	%
6461	33	Barn yard millet,	Minerals only, - -	—	34	1.03	.35	6.44
6462	34	Barn yard millet,	Minerals only, - -	—	28	1.19	.33	7.44
6463	35	Barn yard millet,	Minerals only, - -	—	33	1.32	.44	8.25
6464	36	Barn yard millet,	Minerals only, - -	—	30	1.00	.30	6.25
		Average, -	—	—	**31**	**1.14**	**.36**	**7.10**
6465	37	Barn yard millet,	Minerals + ⅓ nit. ration,	.33⅓	43	1.33	.57	8.31
6466	38	Barn yard millet,	Minerals + ⅓ nit. ration,	.33⅓	46	1.61	.74	10.06
6467	39	Barn yard millet,	Minerals + ⅓ nit. ration,	.33⅓	42	1.15	.48	7.19
6468	40	Barn yard millet,	Minerals + ⅓ nit. ration,	.33⅓	43	1.02	.44	6.38
		Average, -	—	—	**44**	**1.28**	**.56**	**7.99**
6469	41	Barn yard millet,	Minerals + ⅔ nit. ration,	.66⅔	45	1.68	.76	10.50
6470	42	Barn yard millet,	Minerals + ⅔ nit. ration,	.66⅔	53	1.58	.84	9.87
6471	43	Barn yard millet,	Minerals + ⅔ nit. ration,	.66⅔	45	1.74	.78	10.87
6472	44	Barn yard millet,	Minerals + ⅔ nit. ration,	.66⅔	48	1.61	.77	10.06
		Average, -	—	—	**48**	**1.65**	**.79**	**10.33**
6473	45	Barn yard millet,	Minerals + full nit. ration,	1.00	51	1.92	.98	12.00
6474	46	Barn yard millet,	Minerals + full nit. ration,	1.00	54	1.82	.98	11.37
6475	47	Barn yard millet,	Minerals + full nit. ration,	1.00	52	1.68	.87	10.50
6476	48	Barn yard millet,	Minerals + full nit. ration,	1.00	51	1.89	.96	11.81
		Average, -	—	—	**52**	**1.83**	**.95**	**11.42**

The yield from the different pots in the same group was fairly uniform, but the averages of the yields for the different groups varied considerably. Unlike the experiment with Hungarian grass, the yields of millet increased with the increase in nitrogen as fertilizer. This may be due to the larger growth made by the millet and consequently to the greater requirements of the crop for nitrogen. There was a fairly constant increase of nitrogen and of protein in the millet crop of the different groups, corresponding to the amounts of nitrogen used in the fertilizer, but this was less noticeable in the case of the Hungarian grass. These results would seem to indicate that in cases where the nitrogen is largely used in producing growth it does not increase the proportion of nitrogen to such an extent as where less is required for the growth of the crop; and in order to increase more largely the proportion of nitrogen in the crop it may be necessary to use nitrogen in amounts beyond the needs of the crop for growth.

EXPERIMENT WITH SOY BEANS.

The experiment with soy beans comprised pots Nos. 49 to 64 inclusive. It was similar to the experiments of the two years preceding with the same crop except that smaller quantities of nitrogen were used in the fertilizer. The medium early green variety of soy bean was grown. The plants were thinned out when about an inch high, only six being left in each pot. The growth seemed to be normal throughout the season and the appearance of the crops in the different pots was much the same. The results of the experiment are given in Table 80.

The average yield was but very little larger where the largest quantities of nitrogen were used than that where no nitrogen was used. As in similar experiments in 1899 and 1900 there seemed to be no relation between the quantities of nitrogen used and the percentage of nitrogen and of protein in the crop. In fact in the experiment for 1901 the percentage of nitrogen decreased slightly as the amount of nitrogen used for the different groups was increased. Attention is called to this not because the decrease in the percentage of nitrogen had any marked significance, because it was slight, but rather to point out that with soy beans there seems to be no relation

between the nitrogen in the crop and that used as fertilizer. On the whole there seems to be no tendency for nitrogenous fertilizer to improve the feeding value of the soy bean seeds.

TABLE 80.

Nitrogen in fertilizer and in crop in pot experiment with soy bean seed, 1901.

Lab. No.	Pot No.	Sample.	Fertilizer. Kind.	Fertilizer. Amt. of nitrogen per pot.	Total weight crop.	Total nitrogen.		Protein. (N. × 6.25.)
				Gm.	G.	%	Gms	%
6477	49	Soy bean seed,	Mineral fertilizers, - -	—	18	7.02	1.26	43.88
6478	50	Soy bean seed,	Mineral fertilizers, - -	—	18	7.05	1.27	44.06
6479	51	Soy bean seed,	Mineral fertilizers, - -	—	16	7.26	1.16	45.37
6480	52	Soy bean seed,	Mineral fertilizers, - -	—	17	7.24	1.23	45.25
		Average, -	—	—	**17**	**7.14**	**1.23**	**44.64**
6481	53	Soy bean seed,	Minerals + ⅓ nit. ration,	.33⅓	19	7.16	1.36	44.75
6482	54	Soy bean seed,	Minerals + ⅓ nit. ration,	.33⅓	20	7.06	1.41	44.13
6483	55	Soy bean seed,	Minerals + ⅓ nit. ration,	.33⅓	18	7.16	1.29	44.75
6484	56	Soy bean seed,	Minerals + ⅓ nit. ration,	.33⅓	16	7.12	1.14	44.50
		Average, -	—	—	**18**	**7.13**	**1.30**	**44.53**
6485	57	Soy bean seed,	Minerals + ⅔ nit. ration,	.66⅔	21	6.94	1.46	43.38
6486	58	Soy bean seed,	Minerals + ⅔ nit. ration,	.66⅔	22	6.90	1.52	43.13
6487	59	Soy bean seed,	Minerals + ⅔ nit. ration,	.66⅔	19	6.97	1.32	43.56
6488	60	Soy bean seed,	Minerals + ⅔ nit. ration,	.66⅔	19	7.08	1.35	44.25
		Average, -	—	—	**20**	**6.97**	**1.41**	**43.58**
6489	61	Soy bean seed,	Minerals + full nit. ration,	1.00	21	6.98	1.47	43.63
6490	62	Soy bean seed,	Minerals + full nit. ration,	1.00	23	6.51	1.50	40.69
6491	63	Soy bean seed,	Minerals + full nit. ration,	1.00	22	6.98	1.54	43.63
6492	64	Soy bean seed,	Minerals + full nit. ration,	1.00	20	7.09	1.42	44.31
		Average, -	—	—	**21**	**6.89**	**1.48**	**43.07**

SUMMARY AND DEDUCTIONS.

The purpose of the pot experiments was to study the effects of nitrogenous fertilizers on the percentages of nitrogen and protein in some of our common farm crops. In this respect they are similar to the field experiments with nitrogenous fertilizers which the Station has conducted during the past twelve years; but it was thought that with the crops grown in pots the conditions of the experiments would be more fully under control and the results would thus have an increased value, and would serve to verify the results obtained in the field experiments.

The crops were grown in large pots and were protected from rains by a plant shelter, although the plants stood out of doors in pleasant weather. The water used for watering the plants was practically free from nitrogen and was all added artificially. A natural soil in which to grow the crops was taken from field plots to which no nitrogen had been added since 1890. The amounts of nitrogen used, especially in the experiments prior to 1901, were proportionately much larger than in the field experiments, although the ratio of the amounts on the different groups of pots to each other were the same as in the groups of plots of special nitrogen field experiments. All of the pots were supplied with uniform quantities of mineral fertilizers, one group had the "one-third nitrogen ration," one the "two-thirds ration," and one the "full ration," in addition to the minerals.

The results of the past three years' experiments indicate that our common grasses such as orchard grass and meadow fescue are greatly increased in the percentages of nitrogen and of protein by the nitrogen used as a fertilizer. Similar results were obtained with Hungarian grass and millet. The only cereal that has been grown in these experiments is oats. While the experiment has not been fully satisfactory the increase in percentage of protein was much larger where the larger quantities of nitrogen were used as fertilizer. The only legume which has been successfully grown is the soy bean. The seed of this plant was but little increased either in total weight of crop or in the percentage of nitrogen by the nitrogen used as fertilizer.

The practical bearing of the experiments is in the increased feeding value of certain crops following an increase in nitrogen used as fertilizer. Protein is the most expensive nutrient in feeding stuffs, and whatever method can be adopted to increase economically the amount produced on the farm, and thus to lessen the amount to be purchased, is particularly advantageous. These and similar experiments by the Station indicate that nitrogenous fertilizers such as nitrate of soda, dried blood, tankage, or manure from well fed animals, may be so used as to increase considerably the percentages and the total yields of nitrogen and of protein of our common grasses and cereals over what these crops contain when grown without the use of such fertilizers. Nitrogenous fertilizers, on the other hand, are of little value for increasing the percentages of nitrogen and of protein in the legumes, such as soy beans, cow peas and clovers.

ANALYSES OF FODDERS AND FEEDING STUFFS.

REPORTED BY THE DIRECTOR.

The chemical analyses made by the Station during the past year have included complete analyses of about 300 samples of food, feces and urine in connection with the metabolism and digestion experiments with men, 45 samples of various fodders and feeding stuffs used in the dairy herd tests, and 12 samples of crops from field experiments with fertilizers. In addition to these determinations have been made of water and nitrogen in 59 samples of crops from the field experiments, and of nitrogen only in 59 samples of crops from the pot experiments. The methods of analysis were those recommended by the Association of Official Agricultural Chemists, with such minor modifications as have been found of advantage in this laboratory.

The analyses made in connection with the experiments with men will be published in connection with the other details of those investigations. The proportions of nitrogen in the crops from the pot experiments are given in the discussion of those experiments elsewhere in this report (see p. 154). The descriptions and analyses of the materials from the field experiments and the dairy herd tests are given on the following pages.

The details of this article have been written by Mr. R. D. Milner who has also superintended the preparation of the tables. The analyses were made mostly by Mr. E. Osterberg.

Table 81 shows the percentages of nitrogen and protein in the water-free material and of water, dry matter, nitrogen and protein in the fresh substance in the samples of crops from the field experiments. The analyses of these crops have been limited to these determinations because they are the only ones necessary for the purpose of the experiments. In the feeding tests with dairy herds more complete analyses of the fodders and feeding stuffs were required; these are given for the fresh

substance in Table 82 and for the water-free material in Table 83. Analyses of several samples of soy bean seeds and ensilage corn fodder from field experiments are also given in these tables.

According to the usual custom protein is given in the tables as total nitrogen multiplied by the factor 6.25. As pointed out elsewhere in the report (see p. 127), it is understood that the results thus obtained are only approximately correct, but they are believed to be sufficiently so for practical purposes.

In all the tables of analyses two sets of averages are given, the first set being averages of analyses here published for the first time, the second set the averages of all analyses of similar materials thus far made in this laboratory, including those here reported.

DESCRIPTION OF SAMPLES.

The conditions under which the crops of the field experiments were grown are given in the discussion of the experiments on pages 122 to 141 herewith. The following notes give a brief description of the growth on the different plots, the manner in which the different samples were taken, etc. Descriptions of samples of the various fodders and feeding stuffs analyzed in connection with the dairy herd tests discussed on pages 81 to 104 are also given here.

GREEN FODDERS.

Nos. 6252-6260. Ensilage corn.—Grown in 1899 on a series of plots similar to those in the regular special nitrogen plot experiments; analyzed in 1900, but not previously reported. The stalks and leaves were green and succulent; the ears were well glazed. From the total crop on each plot a large sample of about 30 pounds was taken by removing small portions as the crop was being cut up for the silo. The whole was then carefully mixed and a sub-sample was taken and dried at once in a steam drier.

ENSILAGE.

Nos. 6414 and 6423. Corn and soy bean ensilage.—Used in dairy herd tests Nos. 64 and 66 respectively. In sampling, portions were taken from different parts of the silo to the depth of about a foot, and were thoroughly mixed, and from

this a sub-sample was taken. The corn used in making the ensilage was the large dent variety; it was cut late, when the ears were well glazed. The soy beans were the yellow variety; there was a good growth, with pods well formed, when harvested. One load of beans was put into the silo for every two loads of corn.

CURED FODDERS.

Nos. 6493–6512. Stover of white flint corn.—Grown in the special nitrogen experiments of 1901. The samples of stover were taken Oct. 27 and 28, 1901. For a large sample from a half to the whole amount of the crop on each plot was taken. This was cut into pieces about an inch long and thoroughly mixed and from this a sub-sample was taken and dried.

Nos. 6493–6512 were samples of crops grown on the sections at the north ends of the plots, and Nos. 6503–6512 those on the sections at the south ends.

Nos. 6493 and 6494 were from plots 0 and 00. The growth was very slender and small, with few small ears; stalks and leaves pale green in color.

Nos. 6495 and 6496 were from plots 6*a* and 6*b*. There was a medium heavy growth of stalks but the ears were quite light. The stalks and leaves were pale green in color.

No. 6497 was from plot 7. There was a light growth of stalks, pale green in color, and ears were light.

No. 6498 was from plot 8. Heavy growth of stalks, fairly green in color; ears medium heavy.

No. 6499 was from plot 9. Heavy growth of stalks, rich green in color; ears quite heavy.

No. 6500 was from plot 10. Stalks medium heavy, ears quite good; stalks and leaves medium green in color.

No. 6501 was from plot 11. Stalks medium heavy, ears rather small; stalks and leaves medium green in color.

No. 6502 was from plot 12. Slender, spindling growth of stalks, very few ears; stalks reddish in color, leaves medium green.

Nos. 6503 and 6504 were from plots 0 and 00. Slender, small growth, ears very few and small; stalks and leaves pale green in color.

Nos. 6505 and 6506 were from plots 6*a* and 6*b*. Stalks fairly heavy but pale green in color; ears light.

No. 6507 was from plot 7. Medium heavy growth, fairly well eared; leaves and stalks medium green in color.

No. 6508 was from plot 8. Heavy growth well eared; leaves and stalks good color.

No. 6509 was from plot 9. Heavy growth, well eared; leaves and stalks dark green in color.

No. 6510 was from plot 10. Fairly heavy growth, quite well eared; leaves and stalks medium green in color.

No. 6511 was from plot 11 and No. 6512 was from plot 12. On both plots there was a heavy growth, well eared; stalks and leaves dark green in color.

Oat hay.—Used in dairy herd tests. About 50 pounds, composed of small portions taken from different parts of the mow, was cut up into small pieces and thoroughly mixed and sub-sampled.

No. 6389 from dairy herd test No. 59. Hay generally past full bloom when cut, some seed forming; harvested in good condition. Sample taken Dec. 17, 1900.

No. 6402 from dairy herd test No. 61. Oats had made a good growth and were harvested in good condition when a little past full bloom. Sample taken Jan. 14, 1901.

No. 6410 from dairy herd test No. 63. Heavy growth of oats, cut just when they were in the milk stage and well cured. Sample taken Feb. 7, 1901.

No. 6417 from dairy herd test No. 65. Heavy growth of oats harvested when just past full bloom. Sample taken March 12, 1901.

No. 6427 from a dairy herd test not included in the report. Rather poor quality of hay, seeds about half grown when harvested; quite weedy. Sample taken March 4, 1901.

Timothy hay.—No. 6395 from dairy herd test No. 60. Nearly clear timothy, rather fine, cut early; harvested in good condition. Sample taken Dec. 31, 1900, from lot of about 40–50 pounds which was cut up into small pieces and thoroughly mixed.

Hay of mixed grasses.—Used in dairy herd tests. A sample of about 50 pounds was made up of small portions taken from different parts of the mow; this was cut into small pieces and then thoroughly mixed and sub-sampled.

No. 6396 from dairy herd test No. 60. Cut early and harvested in good condition. Sample taken Dec. 31, 1900.

No. 6406 from dairy herd test No. 62. Mixture of timothy and common grasses; rather small growth, cut early, well cured and in good condition. Sample taken Feb. 7, 1901.

No. 6415 from dairy herd test No. 64. Rank growth of grass but mixed with a good many weeds and harvested rather past its prime and in poor condition. Sample taken Feb. 22, 1901.

No. 6418 from dairy herd test No. 65. Good growth, harvested in good season, well cured and in good condition. Sample taken March 12, 1901.

No. 6424 from dairy herd test No. 66. Same lot of hay as that from which sample No. 6415 was taken; rather poor, and not very uniform in quality. Sample No. 6424 taken March 25, 1901.

No. 6426 from dairy herd test not reported. Fair quality, and in medium condition when cut; harvested in fair condition. Sample taken March 4, 1901.

Oat and pea hay.—No. 6428 from dairy herd tests not reported. Heavy growth, good condition when cut, oats a little past bloom; about one-quarter by weight of pea hay. The sample was taken April 4, 1901. About 25–30 pounds was cut into small pieces and thoroughly mixed and sub-sampled.

Black grass hay.—No. 6412 from dairy herd test No. 63. Sample taken Feb. 7, 1901. No. 6420 from dairy herd test No. 65. Sample taken March 12, 1901. The growth was short but extra heavy, cut when just past full bloom and harvested in good condition. In sampling, small portions were taken from different parts of the mow and cut into small pieces which were thoroughly mixed and sub-sampled.

Corn stover.—Used in dairy herd tests.

No. 6390 from dairy herd test No. 59. Stover of white flint corn, which made a good growth of ears. Sample taken on Dec. 17, 1900, from a lot of about 700–800 pounds which on December 14 had been cut into pieces about an inch long; the stover was slightly mouldy and fairly dry.

No. 6397 from dairy herd test No. 60. Stover of flint corn which had eared well. Sample taken Dec. 31, 1900, from pile of 1200–1500 pounds which had been cut into 6-inch lengths. From 30–40 pounds of this was taken from different parts of the pile, cut into smaller pieces and mixed and sub-sampled. The stover was bright and quite dry.

No. 6401 from dairy herd test No. 61. Stover from flint corn that had eared heavily, was not harvested in good condition and was considerably mouldy. Sample was taken Jan. 14, 1901 from pile of 800–900 pounds and cut into small pieces which were mixed and sub-sampled.

No. 6405 from dairy herd test No. 62. Stover of Canada flint corn. Small growth of stalks, eared well. Stover well cured and harvested in good condition. Sample taken Jan. 28, 1901. Small quantities were taken from different parts of the mow and 40–50 pounds was cut into small pieces and thoroughly mixed and sub-sampled.

No. 6409 from dairy herd test No. 63. Stover of dent corn. Extra heavy growth of stalks, well eared, cut early and stacked in field until needed; in good condition when brought in for feeding. Sample taken Feb. 7, 1901, from about a ton which had been cut into small pieces, was made up of small portions taken from different parts of the pile of cut stover.

No. 6419 from dairy herd test No. 65. Similar to sample No. 6409. Sample was taken from different parts of a pile of about 1000 pounds which had previously been cut into small pieces.

MILLING AND BY-PRODUCTS.

The following samples were those of milling products used in the dairy herd tests during the winter of 1899–1900. The samples were taken in such a way as to represent averages of the different feeds used during the tests.

No. 6391 corn meal from dairy herd test No. 59. Sample taken from about 150 pounds of home grown flint corn.

Nos. 6394, 6400 and 6431. Cotton seed meal from dairy herd tests Nos. 59, 60 and a test not reported.

No. 6398. Corn and cob meal from dairy herd test No. 60. Home grown flint corn meal made by grinding the whole ears.

Nos. 6399 and 6429. Wheat bran from dairy herd test No. 60 and one not reported.

No. 6432. Chicago gluten meal from dairy herd test not reported.

No. 6433. Wheat middlings from dairy herd test No. 64.

No. 6430. Brewers' grains from dairy herd test not reported.

No. 6492. Quaker dairy feed from dairy herd test No. 59.

No. 6393. Pillsbury's mixed feed from dairy herd test No. 59.

No. 6403. Grain mixture from dairy herd test No. 61. Made up of 150 lbs. Quaker dairy feed, 300 lbs. wheat bran, 200 lbs. corn meal, 75 lbs. cotton seed meal, 125 lbs. cream gluten meal.

No. 6404. Grain mixture from dairy herd test No. 62. Made up of 300 lbs. corn and cob meal, 400 lbs. wheat bran, 200 lbs. cotton seed meal.

No. 6408. Grain mixture from dairy herd test No. 62. Made up of 25 lbs. cream gluten meal, 75 lbs. wheat bran, 100 lbs. cotton seed meal.

No. 6413. Grain mixture from dairy herd test No. 63. Supposed to be equal parts of corn and cob meal and wheat bran.

No. 6416. Grain mixture from dairy herd test No. 64. Made up of 300 lbs. wheat middlings, 100 lbs. hominy chop, 150 lbs. cotton seed meal.

No. 6421. Grain mixture from dairy herd test No. 65. Made up of 500 lbs. corn and cob meal, 400 lbs. wheat bran, 125 lbs. national gluten feed, 150 lbs. cotton seed meal.

No. 6422. Grain mixture from dairy herd test No. 65. Made up of 100 lbs. corn and cob meal, 100 lbs. cotton seed meal, 100 lbs. national gluten feed.

No. 6425. Grain mixture from dairy herd test No. 66. Made up of 400 lbs. wheat bran, 200 lbs. cotton seed meal, 200 lbs. Chicago gluten meal, 100 lbs. hominy chop.

SEEDS.

Nos. 6513–6532. White flint corn (grain).—Grown in special nitrogen experiments of 1901. Samples Nos. 6513–6522 were from sections at the south ends of the plots, and Nos. 6523–6532 from sections at the north ends. In each case the total amount of corn on a plot was dried until about Dec. 26–Jan. 4, when it was shelled; and on Jan. 22, 1902, about one quart was taken for a sample at the time the total weight of the crop was determined. The sample was sealed in a quart fruit jar. All the samples from the sections at the south ends of the plots excepting No. 6525, were partly mouldy when received at the laboratory.

Nos. 6513 and 6514 were from plots o and oo. The corn was very small and mostly soft, with a few small ears on the plot. Slightly more numerous on plot oo than on plot o.

Nos. 6515 and 6516 were from plots 6*a* and 6*b*. Growth of ears rather light.

No. 6517 was from plot 7. Growth of ears light but well matured.

No. 6518 was from plot 8. Growth of ears good, well matured.

No. 6519 was from plot 9. Growth of ears quite heavy, well matured.

No. 6520 was from plot 10. Growth of ears medium heavy, well matured.

No. 6521 was from plot 11. Growth of ears fairly well matured.

No. 6522 was from plot 12. Growth of ears light, ears small and poorly developed.

Nos. 6523 and 6524 were from plots o and oo. The ears were few and small and not well filled. The sample as received at the laboratory was partly mouldy.

Nos. 6525 and 6526 were from plots 6*a* and 6*b*. The ears were rather light in proportion to the stalks.

Nos. 6527 was from plot 7. Ears were quite good and well matured.

Nos. 6528 and 6529 were from plots 8 and 9. Ears quite heavy, well matured and filled out.

No. 6530 was from plot 10. Ears medium heavy, well matured.

No. 6531 was from plot 11 and No. 6532 was from plot 12. Ears were quite heavy, well matured and filled out.

Nos. 6533–6554. Soy bean seed.—Nos. 6533–6542 were the early white variety grown in the special nitrogen field experiments of 1901. In each case an average sample of about one quart was taken on Jan. 24, 1902, at the time the total crop from each plot was weighed. These samples were sealed in quart jars. Since this is the first time this variety of bean was grown in these experiments complete analyses of a few samples were made in order to obtain an idea of their composition. Nos. 6543–6554 were the medium early green variety grown in the soil tests of 1901. The samples were taken at the same time and in the same manner as those from special nitrogen experiments.

No. 6533 was from plot 0 and No. 6534 from plot 00. The growth of vines was small and pale yellow in color and the seed development was light. The growth was a little better on plot 00 than on plot 0.

Nos. 6535 and 6536 were from plots 6*a* and 6*b*. Growth of vines and seeds somewhat lighter than on nitrogen plots; vines pale yellow in color.

No. 6537 was from plot 7. Growth of vines and seed medium heavy; vines good color.

Nos. 6538 and 6539 were from plots 8 and 9. Growth of vines and seed quite heavy.

No. 6540 was from plot 10. Growth of vines and seed medium heavy, not quite equal to that on plots 11 and 12.

Nos. 6541 and 6542 were from plots 11 and 12. Growth of vines and seed quite heavy; vines good color.

No. 6543 was from plot 0 and 6544 from plot 00, and 6545 from plot 000. A light growth of vines and small proportion of pods.

No. 6546 was from plot A. Vines rather light, dark green in color, seed medium heavy.

No. 6547 was from plot B. Growth of vines and pods medium heavy, better than on plot A.

No. 6548 was from plot C. Vines and seed medium heavy, much the same as on plots A and B.

No. 6549 was from plot D. Heavy growth of vines and seed, better than on plot E.

No. 6550 was from plot E. Medium heavy growth of vines and seed.

No. 6551 was from plot F. Heavy growth of vines and seed; vines lighter than on plots G, X, and Y.

No. 6552 was from plot G. Heavy growth of vines and seed. Growth at harvest lighter than on plots X and Y.

No. 6553 was from plot X, and No. 6554 was from plot Y. Very heavy growth of vines and seed.

TABLE 81.

Composition of samples of field crops grown with different fertilizers in the plot experiments of 1901.

Lab. No.	Kind of Crop.	In Water-free Substance. Nitrogen.	Protein. (N. × 6.25.)	In Fresh Substance. Water.	Dry matter.	Nitrogen.	Protein. (N × 6.25.)
		%	%	%	%	%	%
6493	White flint corn stover,	.98	6.14	31.4	68.6	0.7	4.2
6494	White flint corn stover,	1.33	8.31	28.6	71.4	1.0	5.9
6495	White flint corn stover,	.79	4.97	35.0	65.0	0.5	3.2
6496	White flint corn stover,	.80	4.99	39.9	60.1	0.5	3.0
6497	White flint corn stover,	.73	4.58	36.6	63.4	0.5	2.9
6498	White flint corn stover,	.73	4.58	23.9	76.1	0.6	3.5
6499	White flint corn stover,	.90	5.63	25.3	74.7	0.7	4.2
6500	White flint corn stover,	.76	4.77	35.1	64.9	0.5	3.1
6501	White flint corn stover,	1.08	6.75	37.7	62.3	0.7	4.2
6502	White flint corn stover,	1.48	9.27	26.3	73.7	1.1	6.8
6503	White flint corn stover,	1.33	8.30	29.9	70.1	0.9	5.8
6504	White flint corn stover,	1.51	9.43	23.2	76.8	1.2	7.2
6505	White flint corn stover,	.83	5.15	38.8	61.2	0.5	3.2
6506	White flint corn stover,	.80	4.97	28.1	71.9	0.6	3.6
6507	White flint corn stover,	.85	5.29	43.8	56.2	0.5	3.0
6508	White flint corn stover,	.98	6.10	35.6	64.4	0.6	3.9
6509	White flint corn stover,	.98	6.13	28.7	71.3	0.7	4.4
6510	White flint corn stover,	.89	5.59	49.8	50.2	0.5	2.8
6511	White flint corn stover,	1.04	6.49	43.1	56.9	0.6	3.7
6512	White flint corn stover,	1.01	6.29	34.3	65.7	0.7	4.1
	Average (20),	**.99**	**6.19**	**33.8**	**66.2**	**0.7**	**4.1**
	Average all analyses (271),	**1.05**	**6.56**	**33.1**	**66.9**	**0.7**	**4.1**
6513	White flint corn,	1.52	9.51	13.9	86.1	1.3	8.2
6514	White flint corn,	1.41	8.83	14.4	85.6	1.2	7.6
6515	White flint corn,	1.52	9.48	17.6	82.4	1.3	7.8
6516	White flint corn,	1.40	8.76	15.8	84.2	1.2	7.4
6517	White flint corn,	1.52	9.47	14.9	85.1	1.3	8.1
6518	White flint corn,	1.52	9.48	16.2	83.8	1.3	7.9
6519	White flint corn,	1.57	9.83	16.1	83.9	1.3	8.2
6520	White flint corn,	1.48	9.24	17.5	82.5	1.2	7.6
6521	White flint corn,	1.47	9.22	19.3	80.7	1.2	7.4
6522	White flint corn,	1.58	9.86	18.2	81.8	1.3	8.1
6523	White flint corn,	1.67	10.43	15.0	85.0	1.4	8.9
6524	White flint corn,	1.59	9.96	15.9	84.1	1.3	8.4
6525	White flint corn,	1.23	8.31	17.4	82.6	1.1	6.9
6526	White flint corn,	1.32	8.24	18.8	81.2	1.1	6.7
6527	White flint corn,	1.45	9.06	17.2	82.8	1.2	7.5
6528	White flint corn,	1.62	10.16	19.9	80.1	1.3	8.1
6529	White flint corn,	1.64	10.23	18.2	81.8	1.3	8.4
6530	White flint corn,	1.31	8.17	18.1	81.9	1.1	6.7
6531	White flint corn,	1.61	10.05	12.3	87.7	1.3	7.8
6532	White flint corn,	1.48	9.29	20.5	79.5	1.2	7.4
	Average (20),	**1.49**	**9.38**	**16.9**	**83.1**	**1.2**	**7.7**
	Average all analyses (253),	**1.73**	**10.81**	**17.2**	**82.8**	**1.4**	**9.0**

TABLE 81.—*(Continued.)*

Lab. No.	Kind of Crop.	In Water-free Substance. Nitrogen.	In Water-free Substance. Protein. (N. × 6.25.)	In Fresh Substance. Water.	In Fresh Substance. Dry matter.	In Fresh Substance. Nitrogen.	In Fresh Substance. Protein. (N. × 6.25.)
		%	%	%	%	%	%
6533	Soy bean seed, - -	7.15	44.68	9.1	90.9	6.5	40.6
6534	Soy bean seed, - -	7.34	45.87	8.0	92.0	6.8	42.2
6535	Soy bean seed, - -	6.65	41.57	9.7	90.3	6.0	37.6
6536	Soy bean seed, - -	6.28	39.27	8.6	91.4	5.7	35.9
6537	Soy bean seed, - -	6.77	42.33	9.8	90.2	6.1	38.2
6538	Soy bean seed, - -	7.01	43.83	9.6	90.4	6.3	39.6
6539	Soy bean seed, - -	7.06	44.11	9.3	90.7	6.4	40.0
6540	Soy bean seed, - -	6.45	40.29	8.6	91.4	5.9	36.8
6541	Soy bean seed, - -	6.41	40.07	8.1	91.9	5.9	36.8
6542	Soy bean seed, - -	6.34	39.60	9.5	90.5	5.8	36.4
6543	Soy bean seed, - -	6.80	42.48	11.7	88.3	6.0	37.5
6544	Soy bean seed, - -	6.96	43.52	10.5	89.5	6.2	38.9
6545	Soy bean seed, - -	6.96	43.50	10.4	89.6	6.2	39.0
6546	Soy bean seed, - -	6.82	42.66	11.1	88.9	6.1	37.9
6547	Soy bean seed, - -	7.00	43.73	11.7	88.3	6.2	38.6
6548	Soy bean seed, - -	6.48	40.47	10.6	89.4	5.8	36.2
6549	Soy bean seed, - -	7.03	43.91	10.8	89.2	6.3	39.2
6550	Soy bean seed, - -	6.70	41.90	12.9	87.1	5.8	36.5
6551	Soy bean seed, - -	6.45	40.30	10.0	90.0	5.8	36.3
6552	Soy bean seed, - -	6.73	42.09	11.5	88.5	6.0	37.3
6553	Soy bean seed, - -	6.91	43.17	9.5	90.5	6.3	39.1
6554	Soy bean seed, - -	7.12	44.50	10.1	89.9	6.4	40.0
	Average (22), - -	**6.79**	**42.45**	**10.0**	**90.0**	**6.1**	**38.2**
	Average all analyses (77),	**6.68**	**41.73**	**9.1**	**90.9**	**6.0**	**37.8**

TABLE 82.

Composition of fodders and feeding stuffs analyzed 1900–1901. Calculated to water content at time of taking sample.

Lab. No.	FEEDING STUFFS.	Water.	Protein.	Fat.	Nitrogen-free extract.	Fiber.	Ash.	Fuel value per lb.
	Green fodders.	%	%	%	%	%	%	Cal.
6252	Ensilage, corn,	63.6	3.8	1.3	25.8	4.1	1.4	680
6253	Ensilage, corn,	68.0	3.3	1.2	20.3	5.3	1.9	590
6254	Ensilage, corn,	64.2	3.2	1.5	23.6	5.9	1.6	670
6255	Ensilage, corn,	66.9	3.3	1.2	19.9	7.1	1.6	615
6256	Ensilage, corn,	66.0	3.3	1.4	19.1	8.4	1.8	630
6257	Ensilage, corn,	64.0	3.4	1.4	23.6	5.8	1.8	670
6258	Ensilage, corn,	65.2	3.5	1.3	23.0	5.2	1.8	645
6259	Ensilage, corn,	65.4	3.8	1.2	22.2	5.5	1.9	635
6260	Ensilage, corn,	65.0	3.1	1.2	22.1	6.5	2.1	640
	Average (9),	**65.3**	**3.4**	**1.3**	**22.0**	**6.0**	**1.8**	**640**
	Average all analyses (12),	**67.0**	**3.1**	**1.3**	**20.9**	**6.0**	**1.7**	**610**
	Ensilage.							
6414	Corn and soy bean ensilage,	70.1	2.9	1.3	17.5	6.5	1.7	555
6423	Corn and soy bean ensilage,	70.3	2.8	1.0	17.4	6.5	2.0	540
	Average (2),	**70.2**	**2.8**	**1.2**	**17.5**	**6.5**	**1.8**	**550**
	Cured fodders.							
6389	Hay, oat,	5.3	6.4	3.2	49.4	29.8	5.9	1725
6402	Hay, oat,	13.9	6.0	3.3	45.9	25.1	5.8	1570
6410	Hay, oat,	7.7	6.5	1.5	49.8	29.1	5.4	1650
6417	Hay, oat,	6.2	7.5	2.9	44.5	31.9	7.0	1680
6427	Hay, oat,	9.1	9.5	2.7	43.3	28.6	6.8	1630
	Average (5),	**8.4**	**7.2**	**2.7**	**46.6**	**28.9**	**6.2**	**1650**
	Average all analyses (21),	**10.6**	**8.0**	**3.1**	**44.1**	**28.7**	**5.5**	**1635**
6395	Hay, timothy,	5.9	7.3	3.1	48.1	30.2	5.4	1725
	Average all analyses (6),	**9.6**	**7.0**	**2.9**	**44.8**	**30.1**	**5.6**	**1645**
6396	Hay, mixed grasses,	5.8	8.0	3.7	48.3	28.0	6.2	1725
6406	Hay, mixed grasses,	5.7	7.9	3.2	51.3	26.9	5.0	1735
6411	Hay, mixed grasses,	5.6	6.1	3.6	49.6	30.1	5.0	1745
6415	Hay, mixed grasses,	15.5	6.1	2.9	42.5	27.8	5.2	1545
6418	Hay, mixed grasses,	9.3	6.9	3.2	50.3	25.6	4.7	1675
6424	Hay, mixed grasses,	10.5	7.8	3.2	46.8	24.4	7.3	1605
6426	Hay, mixed grasses,	8.7	8.8	2.7	45.2	28.9	5.7	1655
	Average (7),	**8.7**	**7.4**	**3.2**	**47.7**	**27.4**	**5.6**	**1670**
	Average all analyses (56),	**11.3**	**7.9**	**3.0**	**44.5**	**28.0**	**5.3**	**1620**
6428	Hay, oat and pea,	10.5	10.5	1.8	37.8	30.9	8.5	1550
	Average all analyses (2),	**11.3**	**10.8**	**1.9**	**39.3**	**28.6**	**8.1**	**1545**
6412	Hay, black grass,	6.7	8.8	3.6	49.1	23.8	8.0	1670
6420	Hay, black grass,	12.9	6.5	2.7	48.4	22.2	7.3	1550
	Average (2),	**9.8**	**7.6**	**3.2**	**48.7**	**23.0**	**7.7**	**1610**
6390	Corn stover,	7.9	8.2	1.7	43.3	31.9	7.0	1625
6397	Corn stover,	7.1	4.3	1.8	47.2	32.3	7.3	1635
6401	Corn stover,	27.4	4.9	1.0	35.4	25.2	6.1	1260
6405	Corn stover,	10.8	4.7	2.0	47.0	29.8	5.7	1600
6409	Corn stover,	9.3	5.3	1.5	46.9	32.1	4.9	1630
6419	Corn stover,	12.6	5.4	1.3	47.0	28.9	4.8	1565
	Average (6),	**12.5**	**5.5**	**1.5**	**44.5**	**30.0**	**6.0**	**1550**
	Average all analyses (211),	**38.7**	**3.8**	**1.2**	**31.3**	**20.8**	**4.2**	**1090**

TABLE 82.—*(Continued.)*

Lab. No.	FEEDING STUFFS.	Water.	Protein.	Fat.	Nitrogen-free extract.	Fiber.	Ash.	Fuel value per lb.
		%	%	%	%	%	%	Cal.
	Seeds.							
6551	Soy bean seed,	10.0	36.3	20.6	21.7	5.8	5.6	2055
6552	Soy bean seed,	11.5	37.3	19.9	20.9	5.0	5.4	2015
6554	Soy bean seed,	10.1	40.0	19.4	21.0	4.2	5.3	2030
	Average (3),	**10.5**	**37.9**	**20.0**	**21.2**	**5.0**	**5.4**	**2035**
	Average all analyses (38),	**8.4**	**36.9**	**18.5**	**26.8**	**3.8**	**5.6**	**2035**
	Milling and By-Products.							
6391	Corn meal,	10.6	9.3	4.3	73.1	1.4	1.3	1740
	Average all analyses (28),	**13.0**	**9.5**	**4.5**	**70.0**	**1.5**	**1.5**	**1695**
6394	Cotton seed meal,	7.7	40.1	10.2	30.0	5.0	7.0	1825
6400	Cotton seed meal,	9.9	44.4	12.3	23.1	3.3	7.0	1835
6431	Cotton seed meal,	7.7	41.7	9.6	27.6	6.2	7.2	1810
	Average (3),	**8.4**	**42.1**	**10.7**	**26.9**	**4.8**	**7.1**	**1825**
	Average all analyses (25),	**7.2**	**44.2**	**11.6**	**25.8**	**4.4**	**6.8**	**1875**
6398	Corn and cob meal,	11.7	7.9	4.0	71.3	3.6	1.5	1710
	Average all analyses (20),	**13.0**	**9.5**	**4.2**	**68.5**	**3.3**	**1.5**	**1690**
6432	Chicago gluten meal,	8.7	40.5	2.9	45.1	1.7	1.1	1745
	Average all analyses (15),	**8.8**	**36.9**	**5.4**	**45.5**	**2.4**	**1.0**	**1805**
6399	Wheat bran,	9.2	15.1	4.0	56.5	8.8	6.4	1665
6429	Wheat bran,	9.3	15.5	4.6	53.4	10.6	6.6	1675
	Average (2),	**9.3**	**15.3**	**4.3**	**54.9**	**9.7**	**6.5**	**1665**
	Average all analyses (51),	**9.7**	**16.8**	**5.0**	**53.4**	**9.4**	**5.7**	**1690**
6433	Wheat middlings,	12.4	15.6	2.9	65.2	1.7	2.2	1655
	Average all analyses (18),	**10.4**	**18.1**	**4.9**	**56.6**	**6.0**	**4.0**	**1710**
6430	Brewers' grains,	5.9	25.4	7.3	43.4	14.7	3.3	1860
6392	Quaker dairy feed,	7.5	18.5	4.0	55.3	9.7	5.0	1720
6393	Pillsbury's fancy mixed feed,	8.3	17.4	4.9	56.2	8.2	5.0	1730
6403	Grain mixture,	7.9	18.7	4.9	58.7	6.2	3.6	1760
6404	Grain mixture,	12.0	30.1	5.9	42.3	6.3	3.4	1715
6407	Grain mixture,	10.6	19.2	5.6	53.5	6.5	4.6	1710
6408	Grain mixture,	7.6	32.1	8.2	42.8	5.2	4.1	1835
6413	Grain mixture,	8.7	15.3	4.0	62.0	5.5	4.5	1710
6416	Grain mixture,	7.6	23.4	5.7	55.7	3.8	3.8	1780
6421	Grain mixture,	9.5	18.3	4.8	58.5	5.0	3.9	1725
6422	Grain mixture,	8.0	27.0	6.2	51.7	4.1	3.0	1800
6425	Grain mixture,	7.3	25.9	6.4	48.8	6.1	5.5	1775

TABLE 83.

Composition of water-free substance of fodders and feeding stuffs analyzed in 1899–1900.

Lab. No.	FEEDING STUFFS.	Protein.	Fat.	Nitrogen-free extract.	Fiber.	Ash.	Fuel value.
	Green fodders.	%	%	%	%	%	Cal.
6252	Ensilage, corn,	10.51	3.60	70.71	11.32	3.86	1875
6253	Ensilage, corn,	10.38	3.73	63.34	16.54	6.01	1835
6254	Ensilage, corn,	8.91	4.15	65.92	16.52	4.50	1875
6255	Ensilage, corn,	10.12	3.59	60.05	21.37	4.87	1855
6256	Ensilage, corn,	9.64	4.24	56.22	24.63	5.27	1860
6257	Ensilage, corn,	9.48	3.86	65.64	16.17	4.85	1860
6258	Ensilage, corn,	10.09	3.69	66.13	14.83	5.26	1850
6259	Ensilage, corn,	10.96	3.53	64.12	15.84	5.55	1840
6260	Ensilage, corn,	8.94	3.49	62.96	18.68	5.93	1830
	Average (9),	**9.89**	**3.77**	**63.90**	**17.32**	**5.12**	**1855**
	Average all analyses (12),	**9.52**	**3.79**	**63.10**	**18.40**	**5.19**	**1855**
	Ensilage.						
6414	Corn and soy bean ensilage,	9.86	4.21	58.72	21.60	5.61	1855
6423	Corn and soy bean ensilage,	9.61	3.28	58.46	22.02	6.63	1815
	Average (2),	**9.73**	**3.75**	**58.59**	**21.81**	**6.12**	**1835**
	Cured fodders.						
6389	Hay, oat,	6.80	3.38	52.14	31.46	6.22	1825
6402	Hay, oat,	6.94	3.78	53.34	29.16	6.78	1825
6410	Hay, oat,	6.98	1.65	53.96	31.57	5.84	1790
6417	Hay, oat,	7.99	3.09	47.48	33.96	7.48	1795
6427	Hay, oat,	10.46	2.93	47.60	31.52	7.49	1790
	Average (5),	**7.83**	**2.97**	**50.91**	**31.53**	**6.76**	**1805**
	Average all analyses (21),	**8.94**	**3.43**	**49.39**	**32.06**	**6.18**	**1825**
6395	Hay, timothy,	7.77	3.29	51.17	32.05	5.72	1830
	Average all analyses (6),	**7.79**	**3.16**	**49.53**	**33.36**	**6.16**	**1820**
6396	Hay, mixed grasses,	8.49	3.93	51.30	29.75	6.53	1830
6406	Hay, mixed grasses,	8.42	3.42	54.36	28.52	5.28	1840
6411	Hay, mixed grasses,	6.48	3.80	52.57	31.83	5.32	1850
6415	Hay, mixed grasses,	7.21	3.40	50.29	32.89	6.21	1825
6418	Hay, mixed grasses,	7.58	3.50	55.44	28.28	5.20	1845
6424	Hay, mixed grasses,	8.67	3.58	52.34	27.25	8.16	1795
6426	Hay, mixed grasses,	9.60	3.00	49.47	31.64	6.29	1815
	Average (7),	**8.07**	**3.52**	**52.25**	**30.02**	**6.14**	**1830**
	Average all analyses (56),	**8.89**	**3.34**	**50.19**	**31.58**	**6.00**	**1825**
6428	Hay, oat and pea,	11.69	2.01	42.30	34.53	9.47	1730
	Average all analyses (2),	**12.16**	**2.15**	**44.39**	**32.20**	**9.10**	**1740**
6412	Hay, black grass,	9.44	3.83	52.65	25.48	8.60	1790
6420	Hay, black grass,	7.39	3.06	55.60	25.54	8.41	1775
	Average (2),	**8.42**	**3.44**	**54.13**	**25.51**	**8.50**	**1785**
6390	Corn stover,	8.95	1.82	46.99	34.63	7.61	1760
6397	Corn stover,	4.64	1.94	50.78	34.81	7.83	1760
6401	Corn stover,	6.72	1.41	48.74	34.81	8.32	1740
6405	Corn stover,	5.27	2.30	52.65	33.37	6.41	1795
6409	Corn stover,	5.90	1.64	51.71	35.37	5.38	1800
6419	Corn stover,	6.16	1.54	53.80	33.04	5.46	1795
	Average (6),	**6.27**	**1.78**	**50.78**	**34.34**	**6.83**	**1775**
	Average all analyses (211),	**6.37**	**2.00**	**51.11**	**33.82**	**6.70**	**1780**

TABLE 83.—*(Continued.)*

Lab. No.	FEEDING STUFFS.	Protein.	Fat.	Nitrogen-free extract.	Fiber.	Ash.	Fuel value.
	Seeds.	%	%	%	%	%	Cal.
6551	Soy bean seeds, - - - - -	40.30	22.90	24.07	6.47	6.26	2285
6552	Soy bean seeds, - - - - -	42.09	22.49	23.61	5.67	6.14	2275
6554	Soy bean seeds, - - - - -	44.50	21.54	23.36	4.64	5.96	2255
	Average (3), - - - - -	**42.30**	**22.31**	**23.68**	**5.59**	**6.12**	**2275**
	Average all analyses (38), - -	**40.32**	**20.19**	**29.20**	**4.16**	**6.13**	**2220**
	Milling and By-Products.						
6391	Corn meal, - - - - - -	10.42	4.80	81.76	1.52	1.50	1945
	Average all analyses (28), - -	**10.96**	**5.14**	**80.46**	**1.73**	**1.71**	**1950**
6394	Cotton seed meal, - - - - -	43.40	11.04	32.55	5.47	7.54	1980
6400	Cotton seed meal, - - - - -	49.32	13.60	25.67	3.64	7.77	2035
6431	Cotton seed meal, - - - - -	45.21	10.36	29.87	6.73	7.83	1960
	Average, - - - - - -	**45.98**	**11.67**	**29.36**	**5.28**	**7.71**	**1991**
	Average all analyses (25), - -	**47.68**	**12.46**	**27.83**	**4.72**	**7.31**	**2020**
6398	Corn and cob meal, - - - -	8.93	4.51	80.80	4.08	1.68	1935
	Average all analyses (20), - -	**10.94**	**4.77**	**78.74**	**3.82**	**1.73**	**1940**
6432	Chicago gluten meal, - - -	44.36	3.13	49.43	1.92	1.16	1910
	Average all analyses (15), - -	**40.46**	**5.83**	**49.95**	**2.65**	**1.11**	**1975**
6399	Wheat bran, - - - - - -	16.65	4.38	62.25	9.74	6.98	1835
6429	Wheat bran, - - - - - -	17.10	5.03	58.89	11.72	7.26	1845
	Average (2), - - - - -	**16.87**	**4.71**	**60.57**	**10.73**	**7.12**	**1840**
	Average all analyses (51), - -	**18.64**	**5.54**	**59.13**	**10.42**	**6.27**	**1875**
6433	Wheat middlings, - - - - -	17.84	3.34	74.45	1.92	2.45	1895
	Average all analyses (18), - -	**20.19**	**5.51**	**63.14**	**6.69**	**4.47**	**1905**
6392	Quaker dairy feed, - - - - -	20.01	4.37	59.80	10.47	5.35	1865
6430	Brewers' grains, - - - - -	26.95	7.72	46.18	15.64	3.51	1975
6393	Pillsbury's fancy mixed feed, - -	19.01	5.35	61.29	8.91	5.44	1885
6403	Grain mixture, - - - - -	20.29	5.29	63.78	6.72	3.92	1910
6404	Grain mixture, - - - - -	34.18	6.73	48.06	7.15	3.88	1945
6407	Grain mixture, - - - - -	21.46	6.24	59.88	7.30	5.12	1910
6408	Grain mixture, - - - - -	34.70	8.83	46.35	5.69	4.43	1985
6413	Grain mixture, - - - - -	16.74	4.37	67.95	6.01	4.93	1870
6416	Grain mixture, - - - - -	25.27	6.16	60.30	4.11	4.16	1930
6421	Grain mixture, - - - - -	20.20	5.31	64.64	5.53	4.32	1905
6422	Grain mixture, - - - - -	29.34	6.69	56.21	4.49	3.27	1955
6425	Grain mixture, - - - - -	27.91	6.88	52.62	6.62	5.97	1910

ON THE DIGESTIBILITY AND AVAILABILITY OF FOOD MATERIALS.

BY W. O. ATWATER.

As stated in previous reports, the Station has for several years coöperated with the U. S. Department of Agriculture in experimental inquiries upon the food and nutrition of man. These inquiries have included analyses of food materials, determinations of their heats of combustion and fuel values, dietary studies in which observations were made of the kinds and amounts of food consumed by people of different classes, experiments on the amounts of the nutrients of food digested and made available to the body and finally, so-called metabolism experiments, the purpose of which is the study of some of the fundamental laws of nutrition. A large number of these latter experiments have been made with the respiration calorimeter which was described in the Report of the Station for 1897. The object of these experiments is to study the income and outgo of material and energy in the human body and thus obtain information regarding the ways in which the body uses its food, the values of different food materials for nourishment, and the kinds and amounts fitted to the demands of people of different classes and under different conditions.

One important factor of the nutritive value of a given food is its digestibility. The word digestibility in popular parlance has a by no means definite signification. As used by the physiologist it applies to the chemical changes which the food undergoes in the alimentary canal in order to fit it for absorption and consequent utilization by the body. The particular feature of the digestibility of food in this sense is found in the quantities of the several nutrients which are thus digested, absorbed and made available to the body. The purpose of the present article is to give the results of a considerable number of digestion experiments in their bearing upon this especial subject, namely, the proportions of the nutrients of food materials

which are digested and made available to the body for the chief purposes of nutrition, *i. e.*, the building of tissue and the yielding of energy. The methods pursued in the experiments and the ways in which the results are interpreted have been explained in previous reports.* A brief recapitulation will therefore suffice here.

Of the total food eaten, the larger part is digested, but small portions escape the action of the digestive juices and are excreted in the feces. Along with this undigested residue of the food there is in the feces a certain amount of other material making up the so-called metabolic products. These metabolic products consist largely of the residues of the digestive juices which have been poured into the alimentary canal and not reabsorbed. They contain, however, more or less of other excretory products. Taken together they represent a part of the cost of the digestion of the food.

In the stricter sense, the digestible portion of the food is that which is actually taken into the circulation; it would be found by subtracting the undigested residues from the total food. Thus far, however, no satisfactory and convenient method has been devised for separating the undigested residues from the metabolic products in the feces, consequently the actual digestible portion of the food cannot be easily determined. But the real object of such digestion experiments as are here reported is to find what proportion of food and its several ingredients is actually made available to the body; and as the whole material of the feces, including the undigested residue and metabolic products, is, in this sense, unavailable, the difference between the amounts of the several constituents of the feces and the corresponding constituents of the food, which apparently represents the digestibility, actually represents the availability of the food. In discussions of this sort the words digestible and digestibility are commonly applied to the amounts which are thus made available; that is to say, they represent the difference between total food and total feces; but inasmuch as this difference represents not the total amounts digested but the amounts digested minus the metabolic products, the use of these terms is not entirely accurate. Instead of the above the terms available and availability have been suggested as expressing more exactly the quantities which are actually utilized by

* Report for 1896, p. 163 and 1897, p. 154.

the body for the building and repair of tissue and the yielding of energy, and have been so used in previous reports of the Station.

In accordance with the above explanation, the available nutrients of food are found by subtracting the total amounts in the feces from the total amounts in the food. In like manner, the digestible nutrients, that is, the amounts actually digested, would be found by subtracting the total amounts in the undigested residues from the total amounts in the food. The difference between the available nutrients and the digestible nutrients would thus be represented by the amounts corresponding to the metabolic products.

In deference to common usage we here employ the word "digestible" in some cases as synonymous with "available" but with a very definite understanding that such use of the term "digestible" and the corresponding term "digestibility" is not exactly accurate.

The digestion experiments here reported form part of the metabolism experiments with man in the respiration calorimeter. As has been explained in preceding reports, the data of the metabolism experiments include statistics of the amounts of nutrients consumed in the food and excreted in the feces. Furthermore, each metabolism experiment or series of experiments is preceded by a preliminary period in which the subject while outside the respiration chamber receives the same kind of diet, and the amounts of nutrients in the food and feces are determined. The data thus secured give important information regarding the digestibility and availability of the nutrients of mixed diet.

Subjects.—Three different men served as subjects of the experiments. They were all young, active, in excellent health, their digestion was apparently normal, and they did not find the conditions of the experiment irksome. E. O., an assistant in the laboratory, was a Swede who had lived a number of years in this country. He was 32 years old, and weighed about 70 kilograms (154 pounds). J. F. S., a chemist assisting in conducting the metabolism experiments, was a Canadian, 29 years old, and weighing about 65 kilograms (145 pounds). J. C. W. was a college student, an American, 22 years of age and weighing about 80 kilograms (176 pounds).

Occupation.—The metabolism experiments were both rest and work experiments. During the period preliminary to the rest experiments the subject was generally engaged in his usual occupation, but avoided muscular exertion, conforming his activities as much as possible to those of the coming calorimeter experiment; during his sojourn in the respiration chamber he remained as quiet as practicable. In the work experiments the subject spent the preliminary period at his regular occupation, and in addition, walked or rode a bicycle out doors a considerable distance each day in pleasant weather, or exercised upon a "home trainer" within doors in stormy weather. During the period within the chamber he spent eight hours each day regularly operating a stationary bicycle arranged as an ergometer. The purpose was to perform a reasonable but not excessive amount of work. In only one experiment was the work at all severe.

Diet.—The diet provided palatable food materials with as much variety as was consistent with convenience in preparation and accuracy in sampling and analyzing. For the sake of greater accuracy the number of different materials used was somewhat less in the later than in the earlier experiments. The quantities of nutrients in the diet were in general such as to maintain the body nearly in nitrogen and carbon equilibrium under the conditions of the experiment. In a few cases, however, in which the muscular work was considerable the diet was not quite sufficient for body maintenance and there was consequently more or less draft upon the store of body material. The purpose of the preliminary digestion period was to accustom the subject to the diet and to determine whether under the conditions of the experiment nitrogen equilibrium could be maintained on the diet provided. Any change in diet found necessary or desirable was made during this period; this will explain the slight discrepancies seen in some of the tables between the quantities of food in the preliminary period and in the calorimeter period.

Method.—The general plan of the experiments was the same as has been previously described. Much care was taken in preparing the food materials selected for the diet, and in taking samples for analysis. The separation of the feces was made by means of lampblack administered in gelatin capsules with

the last meal immediately preceding each experiment and with the last meal of each experiment. The total amount of feces for each experiment was collected and prepared for analysis. The food materials and feces were analyzed according to the methods ordinarily followed in this laboratory. The urine was collected for the preliminary period as well as for the metabolism period. The bladder was emptied just before the first meal was taken and all urine was collected thereafter during the experimental periods and the day following the last period. The nitrogen and energy of the urine were determined, so that each digestion experiment includes also a nitrogen metabolism experiment.

As explained above, the differences between the nutrients in the food and the corresponding ingredients in the feces are taken as representing the amounts of the nutrients digested and made available to the body for the purposes of nutrition. The amount of each nutrient thus made available divided by the amount in the food gives the percentage or coefficient of availability.

Not all the energy of the available food is utilized by the body. A portion of the protein of the food is excreted by the kidneys not completely oxidized. The available energy is therefore the energy of the available nutrients less the energy of the materials excreted in the urine. For nearly all of these experiments the quantity of energy in the urine has been directly determined. This determination was interfered with in some of the preliminary experiments and in them the energy of urine has been calculated by multiplying the quantity of available protein by the factor 1.25, it having been found in a number of experiments with healthy men with normal excretion by the kidneys that for every gram of protein absorbed there was on the average 1.25 calories of energy in the unoxidized materials of the urine.

The tables and descriptions which follow give the details of fifty digestion experiments which form part of the metabolism experiments. The first six of these were published in a former report of the station,* but are repeated here because the results as calculated according to revised data differ slightly from those already recorded. The remaining experiments include all those not hitherto published. Besides those here given,

* Report for 1897, pp. 159-166.

the results of fourteen other experiments made in connection with metabolism experiments for another purpose, but also giving valuable information regarding the availability of food in mixed diet, have been published elsewhere.*

DETAILS OF DIGESTION EXPERIMENT NO. 37.

This experiment, which represents the preliminary period of metabolism experiment No. 5, began with breakfast April 26, 1897, and continued eight days, with 24 meals. The subject, E. O., weighed with clothes, 69.3 kilos at the beginning and at the end of the experiment. During the experimental period he was engaged in his usual duties as laboratory assistant, which were not arduous.

TABLE 84.

Digestion experiment No. 37.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
2782	Beef, fried, - - - -	965	330	44.3	277	53	—	17	2034
2783	Beef, dried, - - - -	200	65	7.8	49	16	—	15	406
2781	Eggs, - - - - -	853	201	17.1	107	94	—	8	1517
2785	Butter, - - - - -	275	246	.5	3	243	—	7	2214
2784	Milk, - - - - -	6200	861	35.7	223	334	304	48	5524
2802	Bread, rye, - - - -	2525	1374	34.4	196	8	1170	40	6105
—	Wheat breakfast food, -	50	45	.8	5	1	39	2	204
2786	Sugar, - - - - -	300	300	—	—	—	300	—	1188
2780	Beans, baked, - - - -	1000	291	12.6	79	6	206	22	1341
2779	Pears, canned, - - - -	1200	243	.6	3	11	228	2	934
	Total, - - - -	13568	3956	153.8	942	766	2247	161	21467
2805	Feces, - - - - -	778	160	11.2	70	46	44	40	1053
	Urine, - - - - -	—	—	—	—	—	—	—	1090
	Amount available, - -	—	3796	142.6	872	720	2203	121	19324
			%	%	%	%	%	%	%
	Coefficients of availability,		96.0	92.7	92.6	94.0	98.0	75.2	90.0

During this experiment the subject eliminated 8648.0 grams urine, containing 142.6 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food,

* Memoirs of the National Academy of Sciences, Volume VIII., Sixth Memoir, 1902.

19.2 grams; outgo in urine, 17.9 grams; and in feces, 1.4 grams; implying a loss of .1 gram nitrogen, corresponding to .6 gram protein.

DETAILS OF DIGESTION EXPERIMENT NO. 38.

This experiment represents the period of metabolism experiment No. 5 spent in the respiration chamber. It began with breakfast May 4, 1897, and continued four days, with 12 meals. The subject, E. O., weighed with clothes 69.3 kilos at the beginning, and 68.8 kilos at the end of the experiment. During the experiment he remained as quiet as practicable.

TABLE 85.

Digestion experiment No. 38.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
2782	Beef, fried, - - - -	480	164	22.1	138	26	—	8	1012
2783	Beef, dried, - - - -	100	33	4.0	25	8	—	8	203
2781	Eggs, - - - - -	381	90	7.7	48	42	—	4	677
2785	Butter, - - - -	140	125	.1	1	124	—	4	1127
2784	Milk, - - - - -	3100	431	17.9	112	167	152	24	2762
2802	Bread, rye, - - - -	1300	707	17.6	100	4	603	21	3143
2786	Sugar, - - - - -	140	140	—	—	—	140	—	555
2780	Beans, baked, - - -	500	145	6.2	39	3	103	11	671
2779	Pears, canned, - - -	600	121	.3	2	5	114	1	467
	Total, - - - -	6741	1956	75.9	465	379	1112	81	10617
2806	Feces, - - - - -	502	90	6.6	41	23	26	20	573
	Urine, - - - - -	—	—	—	—	—	—	—	512
	Amount available, - -	—	1866	69.3	424	356	1086	61	9532
			%	%	%	%	%	%	%
	Coefficients of availability, -		95.4	91.3	91.2	93.9	97.7	75.3	89.8

During this experiment the subject eliminated 9120.8 grams urine, containing 72.3 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 19.1 grams; outgo in urine, 18.1 grams, and in feces, 1.7 grams; implying a loss of .7 gram nitrogen, corresponding to 4.2 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 39.

This experiment, representing the preliminary period of metabolism experiment No. 6, began with breakfast May 14, 1897, and continued four days. The subject, E. O., weighed without clothes, 68.6 kilos at the beginning and 66.2 kilos at the end of the experiment. During the period he worked several hours each day, at his usual occupation, and riding a bicycle over country roads or working a stationary machine indoors. The amount of work performed was more than that to which he was accustomed. The quantity of protein in the diet was the same as in the preceding experiment but the energy was largely increased on account of the work.

TABLE 86.

Digestion experiment No. 39.

Lab. No. sample.	Kind of Food.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
2789	Beef, fried,	400	154	19.0	119	35	—	8	968
2788	Ham, deviled,	210	112	5.6	35	77	—	9	914
2790	Eggs,	208	53	4.6	29	24	—	2	401
2793	Butter,	300	265	0.5	3	262	—	7	2386
2799	Milk,	3400	476	16.3	102	184	190	24	3179
2803	Bread, white,	1800	988	23.8	136	29	823	22	4572
2786	Sugar,	200	200	—	—	—	200	—	792
2791	Beans, baked,	500	134	5.8	36	2	96	9	611
2792	Pears, canned,	1200	221	0.6	4	2	215	3	911
	Total,	8218	2603	76.2	464	615	1524	84	14734
2807	Feces,	487	112	7.5	47	29	36	23	768
	Urine,	—	—	—	—	—	—	—	386
	Amount available,	—	2491	68.7	417	586	1488	61	13580
			%	%	%	%	%	%	%
	Coefficients of availability,		95.7	90.1	89.9	95.3	97.6	72.6	91.2

During this experiment the subject eliminated 3680.2 grams urine, containing 44.6 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 19.1 grams; outgo in urine, 11.1 grams, and in feces, 1.9 grams; implying a gain of 6.1 grams nitrogen, corresponding to 38.1 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 40.

This experiment, the part of metabolism experiment No. 6 spent in the respiration chamber, began with breakfast May 18, 1897, and continued four days. The subject, E. O., weighed without clothes, 66.2 kilos at the beginning and 66.7 kilos at the end. During the experiment he worked eight hours each day on a stationary bicycle arranged as an ergometer. The diet was practically the same as in experiment No. 39.

TABLE 87.

Digestion experiment No. 40.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
2789	Beef, fried,	400	154	19.0	119	35	—	9	968
2788	Ham, deviled,	200	107	5.3	33	74	—	8	871
2790	Eggs,	216	54	4.8	30	24	—	2	416
2793	Butter,	300	265	.5	3	262	—	7	2386
2799	Milk,	3400	476	16.3	102	184	190	24	3179
2803	Bread, white,	1800	988	23.8	136	29	823	22	4572
2786	Sugar,	200	200	—	—	—	200	—	792
2791	Beans, baked,	500	134	5.7	36	2	96	9	611
2792	Pears, canned,	1200	221	.6	4	2	215	3	911
	Total,	8216	2599	76.0	463	612	1524	84	14706
2808	Feces,	465	83	6.1	38	19	26	17	555
	Urine,	—	—	—	—	—	—	—	501
	Amount available,	—	2516	69.9	425	593	1498	67	13650
			%	%	%	%	%	%	%
	Coefficients of availability,		96.8	92.0	91.8	96.9	98.3	79.8	92.8

During the experiment the subject eliminated 4797.8 grams urine, containing 65.1 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 19.1 grams; outgo in urine and perspiration, 16.5 grams, and in feces, 1.5 grams; implying a gain of 1.1 grams nitrogen, corresponding to 6.9 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 43.

This experiment, the preliminary period of metabolism experiment No. 8, began with breakfast November 8, 1897, and continued four days. The subject, E. O., weighed with clothes, 72.1 kilos at the beginning and 71.6 kilos at the end. During the period he took but little active exercise aside from his regular work, which was light.

TABLE 88.

Digestion experiment No. 43.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
2820	Beef, fried, - - - - -	600	227	26.4	165	62	—	13	1487
2818	Eggs, - - - - - -	413	96	8.2	51	45	—	4	747
2827	Butter, - - - - -	140	121	0.3	2	119	—	5	1089
2826	Milk, - - - - - -	3400	486	18.6	116	173	197	21	3067
2814	Bread, rye, - - - - -	1310	806	21.0	120	5	681	22	3627
—	Sugar, - - - - - -	160	160	—	—	—	160	—	634
2816	Beans, baked, - - - -	500	133	5.4	34	1	98	11	621
2822	Apples, - - - - -	800	114	0.3	2	4	108	2	468
	Total, - - - - -	7328	2143	80.2	490	409	1244	78	11740
2824	Feces, - - - - - -	442	99	7.0	44	23	32	21	632
	Urine, - - - - - -	—	—	—	—	—	—	—	558
	Amount available, - -	—	2044	73.2	446	386	1212	57	10550
			%	%	%	%	%	%	%
	Coefficients of availability. -		95.4	91.3	91.0	94.4	97.4	73.1	89.9

During this experiment the subject eliminated 5642.7 grams urine, containing 56.6 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 20.1 grams; outgo in urine, 14.2 grams, and in feces, 1.8 grams; implying a gain of 4.2 grams nitrogen, corresponding to 25.6 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 44.

This experiment, the period of metabolism experiment No. 8 passed in the respiration calorimeter, began with breakfast November 12, 1897, and continued four days. The subject, E. O., weighed without clothes, 67.6 kilos at the beginning and 66.5 kilos at the end. During the experiment the subject remained as quiet as practicable.

TABLE 89.

Digestion experiment No. 44.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
2821	Beef, fried,	600	232	30.2	189	43	—	10	1446
2819	Eggs,	380	88	7.5	47	41	—	4	682
2827	Butter,	140	121	0.3	2	119	—	5	1089
2826	Milk,	3400	486	18.6	116	173	197	21	3067
2815	Bread, rye,	1300	796	20.6	117	1	678	22	3572
—	Sugar,	160	160	—	—	—	160	—	634
2817	Beans, baked,	500	130	5.3	33	2	95	11	604
2823	Apples,	800	120	0.3	2	4	114	2	494
	Total,	7280	2133	82.8	506	383	1244	75	11588
2825	Feces,	284	70	5.0	31	17	22	16	467
	Urine,	—	—	—	—	—	—	—	610
	Amount available,	—	2063	77.8	475	366	1222	59	10511
			%	%	%	%	%	%	%
	Coefficients of availability,		96.7	94.0	93.9	95.6	98.2	78.7	90.7

During this experiment the subject eliminated 9272.5 grams urine, containing 78.0 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 20.8 grams; outgo in urine, 19.5 grams, and in feces, 1.3 grams; implying that there was neither a gain nor a loss of nitrogen.

DETAILS OF DIGESTION EXPERIMENT NO. 45.

This experiment, preliminary to metabolism experiment No. 9, began with breakfast January 6, 1898, and continued four days. The subject, E. O., weighed without clothing, 67.9 kilos at the beginning and 68.4 kilos at the end. He was occupied in his usual duties about the laboratory, but did as little muscular work as practicable.

TABLE 90.

Digestion experiment No. 45.

Lab. No. sample.	Kind of Food.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
2835	Beef,	1000	310	41.0	256	54	—	16	1928
2836	Milk, skimmed,	2920	248	15.4	96	3	149	23	1148
2833	Butter,	200	172	.3	2	170	—	8	1552
2834	Bread,	400	212	5.4	31	1	180	10	960
2830	Wheat breakfast food,	500	446	8.0	46	8	392	16	2036
2829	Ginger snaps,	240	219	2.2	13	23	183	9	1046
2832	Sugar,	320	320	—	—	—	320	—	1266
2831	Maize breakfast food,	200	182	3.4	20	18	144	7	889
	Total,	5780	2109	75.7	464	277	1368	89	10825
2837	Feces,	648	122	6.9	43	22	57	24	722
	Urine,	—	—	—	—	—	—	—	526
	Amount available,	—	1987	68.8	421	255	1311	65	9577
			%	%	%	%	%	%	%
	Coefficients of availability,		94.2	90.9	90.8	92.1	95.8	93.0	88.5

During this experiment the subject eliminated 5104.2 grams urine, containing 77.6 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 18.9 grams; outgo in urine, 19.4 grams, and in feces, 1.7 grams; implying a loss of 2.2 grams nitrogen, corresponding to 13.8 grams protein.

DETAILS OF METABOLISM EXPERIMENT NO. 46.

This experiment, representing the period of metabolism experiment No. 9 passed within the respiration calorimeter, began with breakfast January 10, 1898, and continued four days. The subject, E. O., weighed without clothes, 68.4 kilos at the beginning and 67.2 kilos at the end. As this was a rest experiment the subject had as little muscular activity as practicable.

TABLE 91.

Digestion experiment No. 46.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
2835	Beef, - - - - - -	1000	310	41.0	256	54	—	16	1928
2836	Milk, skimmed, - - -	3032	258	16.0	100	3	155	24	1192
2833	Butter, - - - - -	200	172	0.3	2	170	—	8	1552
2834	Bread, - - - - - -	400	212	5.4	31	1	180	10	960
2830	Wheat breakfast food, - -	500	446	8.0	46	8	392	16	2036
2829	Ginger snaps, - - - -	240	219	2.2	13	23	183	9	1046
2832	Sugar, - - - - - -	320	320	—	—	—	320	—	1266
2831	Maize breakfast food, - -	200	182	3.5	21	18	143	7	889
	Total, - - - - -	5892	2119	76.4	469	277	1373	90	10869
2838	Feces, - - - - - -	424	96	5.0	31	17	48	19	594
	Urine, - - - - - -	—	—	—	—	—	—	—	548
	Amount available, - -	—	2023	71.4	438	260	1325	71	9706
			%	%	%	%	%	%	%
	Coefficients of availability, -		95.5	93.5	83.4	93.9	96.5	78.9	89.3

During this experiment the subject eliminated 6702.4 grams urine, containing 73.7 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 19.1 grams; outgo in urine, 18.4 grams, and in feces, 1.3 grams; implying a loss of .6 gram nitrogen, corresponding to 3.6 grams protein.

DETAILS OF METABOLISM EXPERIMENT NO. 49.

This experiment, which was preliminary to metabolism experiment No. 11, began with breakfast March 18, 1898, and continued four days. The subject, E. O., was not weighed at the beginning of the experiment, but at the end weighed without clothes 70 kilos. As the subject was to work during the metabolism experiment he took a considerable amount of exercise on a bicycle and otherwise in addition to his regular duties.

TABLE 92.

Digestion experiment No. 49.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
2851	Beef, - - - - - -	680	216	29.9	187	29	—	12	1306
2853	Butter, - - - - -	480	409	.6	4	405	—	12	3719
2854	Milk, skimmed, - - -	3000	252	15.8	99	3	150	21	1143
2852	Bread, - - - - - -	1200	673	17.1	98	18	557	14	3090
2842	Maize breakfast food, - -	440	411	8.3	50	36	325	8	1952
2840	Wheat breakfast food, - -	300	272	5.3	30	4	238	6	1216
2841	Ginger snaps, - - - -	300	278	2.7	16	19	243	9	1274
—	Sugar, - - - - - -	440	440	—	—	—	440	—	1742
	Total, - - - - -	6840	2951	79.7	484	514	1953	82	15442
2849	Feces, - - - - - -	524	125	7.5	47	35	43	21	790
	Urine, - - - - - -	—	—	—	—	—	—	—	546
	Amount available, - -	—	2826	72.2	437	479	1910	61	14106
			%	%	%	%	%	%	%
	Coefficients of availability, -		95.8	90.6	90.3	93.2	97.8	74.4	91.4

During this experiment the subject eliminated 3404.3 grams urine, containing 51.4 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 19.9 grams; outgo in urine, 12.9 grams, and in feces, 1.9 grams; implying a gain of 5.1 grams nitrogen, corresponding to 31.9 grams protein.

DETAILS OF METABOLISM EXPERIMENT NO. 50.

This experiment, representing the part of metabolism experiment No. 11 passed in the chamber of the calorimeter, began with breakfast May 22, 1898, and continued four days. The subject, E. O., weighed without clothes, 70 kilos at the beginning and 68 kilos at the end. He worked eight hours each day upon the stationary bicycle.

TABLE 93.

Digestion experiment No. 50.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
2851	Beef, - - - - - -	680	216	29.9	187	29	—	12	1306
2853	Butter, - - - - -	480	409	0.6	4	405	—	12	3719
2855	Milk, skimmed, - - -	3000	252	15.8	99	3	150	24	1143
2852	Bread, - - - - - -	1200	673	17.1	98	18	557	14	3090
2842	Maize breakfast food, - -	440	411	8.3	50	36	325	8	1952
2840	Wheat breakfast food, - -	300	272	5.3	30	4	238	6	1216
2841	Ginger snaps, - - - -	300	278	2.7	16	19	243	9	1274
—	Sugar, - - - - - -	440	440	—	—	—	440	—	1742
	Total, - - - - -	6840	2951	79.7	484	514	1953	85	15442
2850	Feces, - - - - - -	563	141	9.0	56	36	49	24	875
	Urine, - - - - - -	—	—	—	—	—	—	—	535
	Amount available, - - -	—	2810	70.7	428	478	1904	61	14032
			%	%	%	%	%	%	%
	Coefficients of availability, -		95.2	88.7	88.4	93.0	97.5	71.8	90.9

During this experiment the subject eliminated 3847.1 grams urine, containing 71.5 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 19.8 grams; outgo in urine and perspiration, 18.1 grams, and in feces, 2.2 grams; implying a loss of .5 gram nitrogen, corresponding to 3.0 grams protein.

DETAILS OF METABOLISM EXPERIMENT NO. 76.

This experiment, preliminary to metabolism experiment No. 13, began with breakfast November 4, 1898, and continued four days. The subject, E. O., performed his usual duties about the laboratory but avoided muscular activity as much as practicable. His weight at the beginning of the experiment was not taken, but at the end just before entering the calorimeter it was without clothes 69.4 kilos.

TABLE 94.

Digestion experiment No. 76.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
2962	Beef, - - - - - -	940	254	37.6	235	19	—	23	1482
2956	Butter, - - - - -	190	164	.3	2	162	—	7	1483
2957	Milk, whole, - - -	2550	326	14.3	89	115	122	20	2037
2958	Milk, skimmed, - - -	600	56	3.8	24	1	31	5	271
2960	Maize breakfast food, - -	200	185	3.5	20	17	148	4	893
2963	Bread, - - - - - -	1100	678	15.2	87	56	535	13	3263
2961	Cookies, - - - - -	100	93	.9	5	11	77	2	446
—	Sugar, - - - - - -	150	155	—	—	—	155	—	614
	Total, - - - - -	5835	1911	75.6	462	381	1068	74	10489
2964	Feces, - - - - - -	151	41	2.4	15	14	12	10	283
	Urine, - - - - - -	—	—	—	—	—	—	—	445
	Amount available, - -	5684	1870	73.2	447	367	1056	64	9761
			%	%	%	%	%	%	%
	Coefficients of availability, -		97.9	96.7	96.8	96.3	98.9	86.5	93.1

During this experiment the subject eliminated 5044.0 grams urine, containing 72.1 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 18.9 grams; outgo in urine, 18.0 grams, and in feces, .6 gram; implying a gain of .3 gram nitrogen, corresponding to 1.9 grams protein.

DETAILS OF METABOLISM EXPERIMENT NO. 77.

This experiment, forming the part of metabolism experiment No. 13 spent in the respiration chamber, began with breakfast November 8, 1898, and continued three days. As this was a rest experiment the subject, E. O., was to remain as quiet as practicable while within the respiration chamber, but he moved about rather more than in earlier and later experiments of a similar kind. His weight without clothing at the beginning of the experiment was 69.4 kilos and at the end 69.6 kilos.

TABLE 95.

Digestion experiment No. 77.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
2962	Beef, - - - - - -	940	255	37.8	236	19	—	23	1482
2956	Butter, - - - - -	180	155	0.3	2	153	—	6	1405
2959	Milk, whole and skim, - -	3000	375	17.3	108	96	171	24	2259
2960	Maize breakfast food, - -	200	185	3.5	21	17	147	4	893
2963	Bread, - - - - - -	1100	678	15.2	87	56	535	13	3263
2961	Cookies, - - - - -	100	93	.8	5	11	77	2	446
—	Sugar, - - - - - -	160	160	—	—	—	160	—	634
	Total, - - - -	5680	1901	74.9	459	352	1090	72	10382
2965	Feces, - - - - - -	296	73	4.5	28	24	21	17	500
	Urine, - - - - - -	—	—	—	—	—	—	—	518
	Amount available, - -	—	1828	70.4	431	328	1069	55	9364
			%	%	%	%	%	%	%
	Coefficients of availability, -		96.2	94.0	93.9	93.2	98.1	76.4	90.2

During this experiment the subject eliminated 8361.7 grams urine, containing 76.5 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 18.7 grams; outgo in urine, 19.5 grams, and in feces, 1.1 grams; implying a loss of 1.9 grams nitrogen, corresponding to 11.7 grams protein.

DETAILS OF METABOLISM EXPERIMENT NO. 78.

This experiment, preliminary to metabolism experiment No. 14, began with breakfast December 17, 1898, and continued three days. The subject, E. O., was not weighed at the beginning of the experiment but at the end he weighed 63.6 kilos. As metabolism experiment No. 14 was a rest experiment the subject during the preliminary period took as little muscular exercise as possible outside of his regular duties.

TABLE 96.

Digestion experiment No. 78.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
2967	Beef, - - - - - -	480	153	21.3	133	20	—	8	943
2970	Butter, - - - - - -	210	182	.5	3	179	—	6	1059
2971	Milk, skimmed, - - -	1525	140	9.3	58	1	81	12	682
2966	Maize breakfast food, - -	150	138	2.7	16	12	110	3	670
2968	Bread, - - - - - -	825	470	10.4	59	23	388	11	2236
2969	Ginger snaps, - - -	90	83	1.0	6	7	70	3	397
	Sugar, - - - - - -	192	192	—	—	—	192	—	760
	Total, - - - -	3472	1358	45.2	275	242	841	43	7347
2973	Feces, - - - - - -	247	51	3.5	22	16	13	9	335
	Urine, - - - - - -	—	—	—	—	—	—	—	316
	Amount available, - - -	—	1307	41.7	253	226	828	34	6696
			%	%	%	%	%	%	%
	Coefficients of availability -		96.3	92.3	92.0	93.4	98.5	79.1	91.1

During this experiment the subject eliminated 2629.7 grams urine, containing 50.2 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 11.3 grams; outgo in urine, 13.4 grams, and in feces, .9 gram; implying a loss of 3.0 grams nitrogen, corresponding to 18.8 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 79.

This experiment, representing the part of metabolism experiment No. 14 within the respiration calorimeter, began with breakfast December 20, 1898, and continued four days. The weight of the subject in his underclothing at the beginning was 63.6 kilos and at the end 62.6 kilos. The subject was as quiet as practicable while in the calorimeter.

TABLE 97.

Digestion experiment No. 79.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
2967	Beef, - - - - - -	640	205	28.5	178	27	—	11	1257
2970	Butter, - - - -	280	242	.5	3	239	—	8	2212
2972	Milk, skimmed, - - -	1800	160	10.9	68	2	90	16	790
2960	Maize breakfast food, - -	200	185	3.5	21	17	147	4	893
2968	Bread, - - - - - -	1240	707	15.7	98	35	574	16	3360
2969	Ginger snaps, - - -	120	111	1.3	7	10	94	3	529
	Sugar, - - - - - -	256	256	—	—	—	256	—	1014
	Total, - - - -	4536	1866	60.4	375	330	1161	58	10055
2974	Feces, - - - - - -	219	49	3.4	21	15	13	8	329
	Urine, - - - - - -	—	—	—	—	—	—	—	568
	Amount available, - -	—	1817	57.0	354	315	1148	50	9158
			%	%	%	%	%	%	%
	Coefficients of availability, -		97.4	94.4	94.4	95.5	98.9	86.2	91.1

During this experiment the subject eliminated 5798.0 grams urine, containing 64.9 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 15.1 grams; outgo in urine, 16.2 grams, and in feces, .9 gram; implying a loss of 2.0 grams nitrogen, corresponding to 12.5 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 84.

This experiment, a part of metabolism experiment No. 23, began with breakfast March 16, 1899, and continued three days. The subject, E. O., weighed without clothes 72.9 kilos at the beginning and 72.7 kilos at the end. During the experiment he had as little muscular activity as possible.

TABLE 98.

Digestion experiment No. 84.

Lab. No. sample.	Kind of Food.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3027	Beef,	450	185	25.1	157	28	—	5	1185
3029	Butter,	165	145	.3	2	143	—	4	1324
3031	Skimmed milk,	3390	288	19.7	122	3	163	27	1386
3032	Bread,	930	542	11.8	74	31	437	12	2687
3004	Parched cereal,	135	125	2.5	15	1	109	2	548
—	Sugar,	120	120	—	—	—	120	—	475
3069	Horseradish,	90	8	.2	1	—	7	—	33
	Total,	5280	1413	59.6	371	206	836	50	7638
3035	Feces,	213	50	3.4	21	11	18	15	343
	Urine,	—	—	—	—	—	—	—	423
	Amount available,	—	1363	56.2	350	195	818	35	6872
			%	%	%	%	%	%	%
	Coefficients of availability,		96.5	94.3	94.3	94.7	97.8	70.0	90.0

During this experiment the subject eliminated 6575.3 grams urine, containing 56.9 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 19.8 grams; outgo in urine, 19.0 grams, and in feces, 1.1 grams; implying a loss of .3 gram nitrogen, corresponding to 1.6 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 85.

This experiment, forming part of metabolism experiment No. 24, began with breakfast March 19, 1899, and continued three days. The subject, E. O., weighed without clothing, 72.7 kilos at the beginning and 72.9 kilos at the end. He remained as quiet as possible during the period. The diet contained an excess of carbohydrates in the form of sugar.

TABLE 99.

Digestion experiment No. 85.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3027	Beef, - - - - - -	450	185	25.1	157	28	—	5	1185
3029	Butter, - - - - -	165	145	.3	2	143	—	4	1324
3031	Skimmed milk, - - -	3390	288	19.6	122	3	163	27	1386
3032	Bread, - - - - - -	930	542	11.8	74	31	437	12	2687
3004	Parched cereal, - - -	135	125	2.5	15	1	109	2	548
—	Sugar, - - - - - -	120	120	—	—	—	120	—	475
—	Rock candy, - - - -	390	164	—	—	—	164	—	1545
3069	Horseradish, - - - -	90	8	.2	1	—	7	—	33
	Total, - - - - -	5670	1577	59.5	371	206	1000	50	9183
3036	Feces, - - - - - -	270	53	3.9	25	13	15	13	347
	Urine, - - - - - -	—	—	—	—	—	—	—	407
	Amount available, - -	—	1524	55.6	346	193	985	37	8429
			%	%	%	%	%	%	%
	Coefficients of availability, -		96.6	93.4	93.3	93.7	98.5	74.0	91.8

During this experiment the subject eliminated 5957.9 grams urine, containing 54.8 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 19.8 grams; outgo in urine, 18.2 grams, and in feces, 1.3 grams; implying a gain of .3 gram nitrogen, corresponding to 1.7 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 147.

This experiment, which was preliminary to metabolism experiment No. 25, began with breakfast January 19, 1900, and continued four days. The subject, J. F. S., was a chemist, employed in connection with the investigations. His duties were not arduous. His weight in underclothing at the end of the period was 63.8 kilos. This was the first experiment with this subject. According to the purpose of the metabolism experiment the diet contained an excess of fat.

TABLE 100.

Digestion experiment No. 147.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3165	Beef, - - - - - -	340	125	18.2	114	11	—	4	738
3166	Butter, - - - - -	392	344	1.0	6	338	—	14	3144
3172	Milk, - - - - - -	4000	420	27.2	168	32	220	20	1956
3164	Bread, - - - - - -	1200	721	17.5	100	25	596	16	3366
3168	Parched cereal, - - -	200	185	3.7	21	3	161	4	827
3167	Ginger snaps, - - -	280	262	2.9	16	25	221	5	1241
—	Sugar, - - - - - -	80	80	—	—	—	80	—	317
	Total, - - - -	6492	2137	70.5	425	434	1278	63	11589
3170	Feces, - - - - - -	294	69	4.1	26	14	29	19	452
	Urine, - - - - - -	—	—	—	—	—	—	—	515
	Amount available, - -	—	2068	66.4	399	420	1249	44	10622
			%	%	%	%	%	%	%
	Coefficients of availability, -		96.8	94.2	93.9	96.8	97.7	69.8	91.7

During this experiment the subject eliminated 4523.5 grams urine, containing 66.5 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 17.6 grams; outgo in urine, 16.6 grams, and in feces, 1.0 grams; implying neither gain nor loss of nitrogen.

DETAILS OF DIGESTION EXPERIMENT NO. 148.

This experiment, the second period of metabolism experiment No. 25, began with breakfast January 23, 1900, and continued three days. The subject, J. F. S., weighed the same at the end as at the beginning, 63.8 kilos. As this was a rest experiment he remained quiet while in the respiration chamber. The diet contained an excess of fat.

TABLE 101.

Digestion experiment No. 148.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3165	Beef, - - - - - -	255	94	13.7	86	8	—	3	554
3166	Butter, - - - - - -	294	258	.7	5	253	—	10	2358
3169	Milk, skimmed, - - -	3000	294	20.4	129	12	153	24	1464
3164	Bread, - - - - - -	900	541	13.1	75	19	447	12	2525
3168	Parched cereal, - - -	150	139	2.8	16	3	120	3	620
3167	Ginger snaps, - - -	210	196	2.2	12	18	166	4	931
—	Sugar, - - - - - -	60	60	—	—	—	60	—	238
	Total, - - - - -	4869	1582	52.9	323	313	946	56	8690
3171	Feces, - - - - - -	121	50	2.9	18	8	24	16	332
	Urine, - - - - - -	—	—	—	—	—	—	—	440
	Amount available, - - -	—	1532	50.0	305	305	922	40	7918
			%	%	%	%	%	%	%
	Coefficients of availability, -		96.8	94.5	94.4	97.4	97.4	71.4	91.1

During this experiment the subject eliminated 3738.0 grams urine, containing 49.2 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 17.7 grams; outgo in urine, 16.4 grams, and in feces, 1.0 grams; implying a gain of .3 gram nitrogen, corresponding to 1.9 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 149.

This experiment, preliminary to metabolism experiment No. 26, began with breakfast February 10, 1900, and continued four days. The subject, J. F. S., weighed in underclothes 64 kilos at the end of the period. During the experiment he performed as little muscular activity as possible aside from his regular duties in the laboratory, which were light. The diet in the experiment contained an excess of fat.

TABLE 102.

Digestion experiment No. 149.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3176	Beef,	340	123	18.4	113	10	—	3	747
3177	Butter,	374	327	1.0	6	321	—	10	2993
3178	Milk, skimmed,	4000	420	26.8	168	20	232	32	1896
3180	Bread,	800	475	11.4	65	13	397	10	2242
3181	Ginger snaps,	240	227	2.4	14	20	193	4	1064
3168	Parched cereal,	200	184	3.7	21	3	160	4	827
—	Sugar,	75	75	—	—	—	75	—	297
	Total,	6029	1831	63.7	387	387	1057	63	10066
3182	Feces,	411	112	7.0	44	23	45	35	737
	Urine,	—	—	—	—	—	—	—	518
	Amount available,	—	1719	56.7	343	364	1012	28	8811
			%	%	%	%	%	%	%
	Coefficients of availability		93.9	89.0	88.6	94.1	95.7	44.4	87.5

During this experiment the subject eliminated 4939.9 grams urine, containing 64.3 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 15.9 grams; outgo in urine, 16.1 grams, and in feces, 1.8 grams; implying a loss of 2.0 grams nitrogen, corresponding to 12.5 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 150.

This experiment formed part of metabolism experiment No. 26, which was a rest experiment with an excess of fat in the diet. It began with breakfast February 14, 1900, and continued three days. The subject, J. F. S., weighed in underclothing 64 kilos at the beginning and at the end of the experiment.

TABLE 103.

Digestion experiment No. 150.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3176	Beef, - - - - -	255.0	93	13.8	86	7	—	2	560
3177	Butter, - - - - -	280.5	246	.7	5	241	—	7	2245
3179	Milk, skimmed, - -	3000.0	276	20.1	126	9	141	24	1386
3180	Bread, - - - - -	600.0	356	8.5	49	10	297	8	1682
3181	Ginger snaps, - - -	180.0	170	1.8	10	15	145	3	798
3168	Parched cereal, - - -	150.0	139	2.8	16	2	121	3	620
—	Sugar, - - - - -	45.0	45	—	—	—	45	—	178
	Total, - - - -	4510.5	1325	47.7	292	284	749	47	7469
3183	Feces, - - - - -	237.0	49	3.3	21	8	20	16	317
	Urine, - - - - -	—	—	—	—	—	—	—	385
	Amount available, - -	—	1276	44.4	271	276	729	31	6767
			%	%	%	%	%	%	%
	Coefficients of availability,		96.3	93.1	92.8	97.2	97.3	66.0	90.6

During this experiment the subject eliminated 4083.0 grams urine, containing 46.2 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 15.9 grams; outgo in urine, 15.3 grams, and in feces, 1.1 grams; implying a loss of .5 gram nitrogen, corresponding to 3.3 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 152.

This experiment formed a part of metabolism experiment No. 28, which was a rest experiment with an excess of carbohydrates in the diet. It began with breakfast February 20, 1900, and continued three days. The subject, J. F. S., weighed in underclothes 63.7 kilos at the beginning and 64 kilos at the end of the experiment.

TABLE 104.

Digestion experiment No. 152.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3176	Beef,	255	93	13.8	86	7	—	2	560
3177	Butter,	90	78	.2	1	77	—	2	720
3179	Milk, skimmed,	3000	276	20.1	126	9	141	24	1386
3180	Bread,	600	356	8.5	49	10	297	8	1682
3181	Ginger snaps,	180	170	1.8	10	15	145	3	798
3168	Parched cereal,	150	140	2.8	16	3	121	3	620
	Sugar,	429	429	—	—	—	429	—	1699
	Total,	4704	1542	47.2	288	121	1133	42	7465
3185	Feces,	220	51	3.7	23	12	16	13	335
	Urine,	—	—	—	—	—	—	—	384
	Amount available,	—	1491	43.5	265	109	1117	29	6746
			%	%	%	%	%	%	%
	Coefficients of availability,		96.7	92.2	92.0	90.1	98.6	69.0	90.4

During this experiment the subject eliminated 3664.5 grams urine, containing 45.8 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 15.8 grams; outgo in urine, 15.3 grams, and in feces, 1.2 grams; implying a loss of .7 gram nitrogen, corresponding to 4.5 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 153.

This experiment, preliminary to metabolism experiment No. 29, began with breakfast March 12, 1900, and continued four days. The subject, J. F. S., weighed in underclothes at the beginning of the experiment 68.9 kilos and at the end 64.5 kilos. During the period of the experiment he took a considerable amount of muscular exercise each day. The diet contained an excess of carbohydrates.

TABLE 105.

Digestion experiment No. 153.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3186	Beef, - - - - - -	232	90	13.3	83	7	—	2	540
3187	Butter, - - - - - -	158	138	.3	2	136	—	5	1272
3188	Milk, whole, - - -	3600	506	23.4	146	198	162	25	3276
3192	Bread, - - - - - -	1200	747	18.0	103	24	620	16	3516
3181	Ginger snaps, - - -	300	283	3.0	17	25	241	5	1330
3193	Parched cereal, - - -	300	282	5.8	33	4	245	6	1261
—	Sugar, - - - - - -	612	612	—	—	—	612	—	2424
	Total, - - - - -	6402	2658	63.8	384	394	1880	59	13619
3194	Feces, - - - - - -	239	61	3.5	22	14	25	14	395
	Urine, - - - - - -	—	—	—	—	—	—	—	527
	Amount available, - - -	—	2597	60.3	362	380	1855	45	12697
			%	%	%	%	%	%	%
	Coefficients of availability, -		97.7	94.5	94.3	96.4	98.7	76.3	93.2

During this experiment the subject eliminated 3434.5 grams urine, containing 59.8 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 16.0 grams; outgo in urine, 16.0 grams, and in feces, .9 gram; implying a loss of .9 gram nitrogen, corresponding to 5.6 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 154.

This experiment, a part of metabolism experiment No. 29, began with breakfast March 16, 1900, and continued three days. The diet contained an excess of carbohydrates. The subject, J. F. S., weighed in underclothes at the beginning of the experiment 63.8 kilos and at the end 64.1 kilos. During the experiment the subject was engaged eight hours a day in work upon the stationary bicycle.

TABLE 106.

Digestion experiment No. 154.

Lab. No. sample.	Kind of Food.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3186	Beef, - - - - -	174	67	10.0	62	5	—	2	405
3187	Butter, - - - - -	141	124	.3	2	122	—	5	1135
3189	Milk, whole, - - -	2700	397	17.8	111	151	135	22	2525
3192	Bread, - - - - - -	900	560	13.5	77	18	465	12	2637
3181	Ginger snaps, - - -	225	213	2.2	13	19	181	4	998
3193	Parched cereal, - - -	225	211	4.3	25	3	183	5	945
—	Sugar, - - - - - -	459	459	—	—	—	459	—	1818
	Total, - - - - -	4824	2031	48.1	290	318	1423	50	10463
3195	Feces, - - - - - -	177	43	2.6	16	9	18	10	279
	Urine, - - - - - -	—	—	—	—	—	—	—	402
	Amount available, - -	—	1988	45.5	274	309	1405	40	9782
			%	%	%	%	%	%	%
	Coefficients of availability, -		97.9	94.6	94.5	97.2	98.7	80.0	93.5

During this experiment the subject eliminated 2362.9 grams urine, containing 47.3 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 16.0 grams; outgo in urine and perspiration, 16.0 grams, and in feces, .8 gram; implying a loss of .8 gram nitrogen, corresponding to 5.0 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 156.

This experiment, which was a part of metabolism experiment No. 31, began with breakfast March 22, 1900, and continued three days. The diet contained an excess of fat. The subject, J. F. S., weighed 64.1 kilos at the beginning and 64.5 kilos at the end of the experiment. During the experiment he was engaged eight hours each day at work upon the stationary bicycle.

TABLE 107.

Digestion experiment No. 156.

Lab. No. sample.	Kind of Food.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3186	Beef, - - - - -	174.0	67	10.0	62	5	—	2	405
3187	Butter, - - - - -	331.5	290	.7	4	286	—	11	2668
3191	Milk, - - - - -	2700.0	396	17.6	110	151	135	22	2535
3192	Bread, - - - - -	900.0	560	13.5	77	18	465	12	2637
3181	Ginger snaps, - - - -	225.0	213	2.3	13	19	181	4	998
3193	Parched cereal, - - -	225.0	211	4.3	25	3	183	5	945
—	Sugar, - - - - -	75.0	75	—	—	—	75	—	297
	Total, - - - - -	4630.5	1812	48.4	291	482	1039	56	10485
3197	Feces, - - - - -	160.0	41	2.4	15	8	18	11	272
	Urine, - - - - -	—	—	—	—	—	—	—	389
	Amount available, - -	—	1771	46.0	276	474	1021	45	9824
			%	%	%	%	%	%	%
	Coefficients of availability,		97.7	95.0	94.8	98.3	98.2	80.4	93.7

During this experiment the subject eliminated 2482.8 grams urine, containing 46.3 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 16.1 grams; outgo in urine and perspiration, 15.6 grams, and in feces, .8 gram; implying a loss of .3 gram nitrogen, corresponding to 2.3 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 157.

This experiment, preliminary to metabolism experiment No. 32, began with breakfast April 16, 1900, and continued four days. The diet in the experiment contained an excess of fat. The subject, J. F. S., weighed in underclothes 66.2 kilos at the end of the experiment. In addition to his regular duties he took a considerable amount of exercise each day.

TABLE 108.

Digestion experiment No. 157.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3205	Beef, - - - - - -	232	80	11.9	74	6	—	2	481
3206	Butter, - - - - -	398	353	.8	5	348	—	11	3268
3199	Milk, - - - - - -	3980	573	26.3	163	199	211	32	3642
3204	Bread, - - - - - -	1200	731	16.6	94	30	607	16	3443
3207	Ginger snaps, - - - -	300	284	2.6	15	22	247	6	1330
3193	Parched cereal, - - -	300	281	5.8	33	4	244	6	1260
—	Sugar, - - - - - -	140	140	—	—	—	140	—	554
	Total, - - - - -	6550	2442	64.0	384	609	1449	73	13978
3208	Feces, - - - - - -	430	109	6.0	37	26	46	22	756
	Urine, - - - - - -	—	—	—	—	—	—	—	505
	Amount available, - - -	—	2333	58.0	347	583	1403	51	12717
			%	%	%	%	%	%	%
	Coefficients of availability, -		95.5	90.6	90.4	95.7	96.8	69.9	91.0

During this experiment the subject eliminated 3238.9 grams urine, containing 61.2 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 16.0 grams; outgo in urine, 15.3 grams, and in feces, 1.5 grams; implying a loss of .8 gram nitrogen, corresponding to 5.0 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 158.

This experiment, a part of metabolism experiment No. 32, began with breakfast April 20, 1900, and continued three days. There was an excess of fat in the diet. The subject, J. F. S., weighed in underclothes at the beginning 66.2 kilos and at the end 64.9 kilos. He worked eight hours each day upon the stationary bicycle.

TABLE 109.

Digestion experiment No. 158.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3205	Beef, - - - - - -	174	61	8.9	56	5	—	2	361
3206	Butter, - - - - -	291	259	.6	4	255	—	8	2389
3200	Milk, - - - - - -	3060	423	20.2	126	153	144	24	2769
3204	Bread, - - - - - -	900	548	12.4	71	23	454	12	2582
3207	Ginger snaps, - - - -	225	212	2.0	11	16	185	5	998
3193	Parched cereal, - - -	225	211	4.3	25	3	183	5	945
	Sugar, - - - - - -	105	105	—	—	—	105	—	416
	Total, - - - - -	4980	1819	48.4	293	455	1071	56	10460
3209	Feces, - - - - - -	293	63	3.5	22	13	28	15	425
	Urine, - - - - - -	—	—	—	—	—	—	—	358
	Amount available, - -	—	1756	44.9	271	442	1043	41	9677
			%	%	%	%	%	%	%
	Coefficients of availability, -		96.5	92.8	92.5	97.1	97.4	73.2	92.5

During this experiment the subject eliminated 3829.6 grams urine, containing 46.0 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 16.1 grams; outgo in urine and perspiration, 15.7 grams, and in feces, 1.2 grams; implying a loss of .8 gram nitrogen, corresponding to 5.0 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 160.

This experiment, a part of metabolism experiment No. 34, began with breakfast April 26, 1900, and continued three days. There was an excess of sugar in the diet. The subject, J. F. S., weighed in underclothes at the beginning of the experiment 64.9 kilos and at the end 65.4 kilos. He was engaged eight hours each day in muscular work upon the stationary bicycle.

TABLE 110.

Digestion experiment No. 160.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3205	Beef,	174	61	8.9	56	5	—	2	361
3206	Butter,	105	93	.2	1	92	—	3	862
3202	Milk,	3060	417	20.2	126	159	132	24	2794
3204	Bread,	900	548	12.4	71	23	454	12	2582
3207	Ginger snaps,	225	212	2.0	11	16	185	5	998
3193	Parched cereal,	225	211	4.3	25	3	183	5	945
—	Sugar,	489	489	—	—	—	489	—	1936
	Total,	5178	2031	48.0	290	298	1443	51	10478
3211	Feces,	256	60	3.5	22	15	23	16	377
	Urine,	—	—	—	—	—	—	—	379
	Amount available,	—	1971	44.5	268	283	1420	35	9722
			%	%	%	%	%	%	%
	Coefficients of availability,		97.1	92.7	92.4	95.0	98.4	68.6	92.8

During this experiment the subject eliminated 2855.8 grams urine, containing 48.9 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 16.0 grams; outgo in urine and perspiration, 16.7 grams, and in feces, 1.2 grams; implying a loss of 1.9 grams nitrogen, corresponding to 11.9 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 189.

This experiment, preliminary to metabolism experiment No. 35, began with breakfast December 5, 1900, and continued four days, with an ordinary mixed diet. The subject, J. C. W., was a college student. His weight was not taken at the beginning of the experiment but at the end it was 76.1 kilos. During the experiment he took as little muscular exercise as practicable.

TABLE III.

Digestion experiment No. 189.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3241	Beef,	400	152	22.5	140	12	—	4	908
3242	Butter,	100	87	.3	2	85	—	3	775
3243	Milk, whole,	3400	456	18.7	116	170	170	24	—
3245	Bread,	1200	694	15.6	89	48	557	11	3340
3246	Shredded wheat,	200	181	3.4	19	3	159	3	815
3247	Ginger snaps,	200	182	1.9	11	14	157	4	848
—	Sugar,	80	80	—	—	—	80	—	317
	Total,	5580	1832	62.4	377	332	1123	49	7003
3248	Feces,	277	56	4.2	26	12	18	11	333
	Urine,	—	—	—	—	—	—	—	547
	Amount available,	—	1776	58.2	351	320	1105	38	6123
			%	%	%	%	%	%	%
	Coefficients of availability,		97.0	93.3	93.1	96.4	98.4	77.6	87.4

During this experiment the subject eliminated 3154.8 grams urine, containing 63.7 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 15.6 grams; outgo in urine, 15.9 grams, and in feces, 1.1 grams; implying a loss of 1.4 grams nitrogen, corresponding to 8.7 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 190.

This experiment, part of metabolism experiment No. 35, began with breakfast December 8, 1900, and continued four days. The subject, J. C. W., weighed at the beginning of the experiment 76.1 kilos and at the end 75.9 kilos. During the sojourn in the respiration calorimeter he remained as quiet as practicable.

TABLE 112.

Digestion experiment No. 190.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3241	Beef,	400	153	22.5	141	12	—	4	908
3242	Butter,	100	87	.3	2	85	—	3	775
3244	Milk, whole,	3400	468	20.4	129	180	159	24	3072
3245	Bread,	1200	694	15.6	89	48	557	11	3340
3246	Shredded wheat,	200	181	3.4	19	3	159	3	816
3247	Ginger snaps,	200	182	—	11	14	157	4	848
	Sugar,	80	80	2.0	—	—	80	—	317
	Total,	5580	1845	64.2	391	342	1112	49	10076
3249	Feces,	395	72	4.9	31	16	25	15	440
	Urine,	—	—	—	—	—	—	—	540
	Amount available,	—	1773	59.7	360	326	1087	34	9096
			%	%	%	%	%	%	%
	Coefficients of availability,		96.1	93.0	92.1	95.3	97.8	69.4	90.3

During this experiment the subject eliminated 5683.4 grams urine, containing 63.4 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 16.0 grams; outgo in urine, 15.8 grams, and in feces, 1.2 grams; implying a loss of 1.0 gram nitrogen, corresponding to 6.4 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 192.

This experiment, preliminary to metabolism experiment No. 37, began with breakfast January 8, 1901, and continued three days. The diet during the experiment contained an excess of carbohydrates. The weight of the subject, J. C. W., at the beginning of the experiment was not taken, but at the end was in underclothes 77 kilos. During the experiment he took a regular amount of muscular exercise each day.

TABLE 113.

Digestion experiment No. 192.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3251	Beef, - - - - - -	255	94	13.9	87	7	—	2	574
3253	Butter, - - - - -	60	52	.2	1	51	—	1	463
3254	Milk, - - - - - -	1500	208	8.4	53	83	72	11	1300
3256	Bread, - - - - - -	1350	761	17.0	97	31	633	12	3606
3257	Graham crackers, - -	150	143	2.1	12	15	116	2	697
3246	Shredded wheat, - - -	150	135	2.5	14	2	119	2	611
3247	Ginger snaps, - - -	225	205	2.2	13	16	176	5	954
3258	Milk sugar, - - - -	150	142	—	—	—	142	—	558
	Total, - - - - -	3840	1740	46.3	277	205	1258	35	8763
3259	Feces, - - - - - -	246	51	4.1	26	7	18	7	285
	Urine, - - - - - -	—	—	—	—	—	—	—	531
	Amount available, - -	—	1689	42.2	251	198	1240	28	7947
			%	%	%	%	%	%	%
	Coefficients of availability, -		97.2	92.0	90.6	96.6	98.6	80.0	90.7

During this experiment the subject eliminated 3053.4 grams urine, containing 58.3 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 11.6 grams; outgo in urine, 14.6 grams, and in feces, 1.0 gram; implying a loss of 4.0 grams nitrogen, corresponding to 25.0 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 193.

This experiment was a part of metabolism experiment No. 37, a work experiment with an excess of carbohydrates in the diet. It began with breakfast January 11, 1901, and continued four days. The subject, J. C. W., in underclothes weighed 77 kilos at the beginning and 74.6 kilos at the end of the experiment. He worked eight hours a day upon the stationary bicycle.

TABLE 114.

Digestion experiment No. 193.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3251	Beef, - - - - - -	340	126	18.6	116	10	—	3	764
3263	Beef, - - - - - -	100	36	5.3	33	3	—	1	212
3253	Butter, - - - - -	80	69	.2	1	68	—	2	616
3255	Milk, - - - - - -	2000	290	11.2	70	110	110	14	1888
3256	Bread, - - - - - -	1800	1015	22.7	130	41	844	16	4808
3257	Graham crackers, - - -	200	190	2.8	16	20	154	3	928
3247	Ginger snaps, - - -	300	273	3.0	17	21	235	7	1272
3258	Milk sugar, - - - -	360	342	—	—	—	342	—	1340
—	Sugar, - - - - - -	560	560	—	—	—	560	—	2216
3246	Shredded wheat, - - -	200	181	3.4	19	3	159	3	816
	Total, - - - - -	5940	3082	67.2	402	276	2404	49	14860
3260	Feces, - - - - - -	4145	86	6.3	40	16	30	15	506
·	Urine, - - - - - -	—	—	—	—	—	—	—	531
	Amount available, - - -	—	2996	60.9	362	260	2374	34	13823
			%	%	%	%	%	%	%
	Coefficients of availability, -		97.2	90.6	90.1	94.2	98.8	69.4	93.0

During this experiment the subject eliminated 3982.8 grams urine, containing 66.3 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 16.8 grams; outgo in urine and perspiration, 16.9 grams, and in feces, 1.6 grams; implying a loss of 1.7 grams nitrogen, corresponding to 10.8 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 194.

This experiment, a part of metabolism experiment, No. 38, was a work experiment, with an excess of fat in the diet. It began with breakfast January 15, 1901, and continued four days. The subject, J. C. W., weighed in underclothes 74.1 kilos at the beginning and 73.5 kilos at the end of the experiment. The work consisted of pedalling a stationary bicycle for eight hours each day.

TABLE 115.

Digestion experiment No. 194.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3251	Beef,	100	37	5.5	34	3	—	1	225
3263	Beef,	100	36	5.3	33	3	—	1	213
3252	Deviled ham,	300	170	7.4	46	124	—	12	1422
3253	Butter,	440	377	1.3	6	371	—	9	3396
3262	Milk,	5400	777	30.2	189	270	318	38	4925
3256	Bread,	1000	564	12.6	72	23	469	9	2671
3246	Shredded wheat,	200	181	3.4	19	3	159	3	815
3247	Ginger snaps,	200	182	2.0	11	14	157	4	848
—	Sugar,	80	80	—	—	—	80	—	317
	Total,	7820	2404	67.7	410	811	1183	77	14832
3261	Feces,	472	88	4.8	30	27	31	25	612
	Urine,	—	—	—	—	—	—	—	621
	Amount available,	—	2316	63.3	380	784	1152	52	13599
			%	%	%	%	%	%	%
	Coefficients of availability,		96.4	93.5	92.7	96.7	97.4	67.5	91.7

During this experiment the subject eliminated 4033.2 grams urine, containing 81.1 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 16.9 grams; outgo in urine and perspiration, 20.6 grams, and in feces, 1.2 grams; implying a loss of 4.9 grams nitrogen, corresponding to 30.5 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 195.

This experiment, which was preliminary to metabolism experiment No. 40, began with breakfast February 22, 1901, and continued four days. The diet contained an excess of carbohydrates. The weight of the subject, J. C. W., was not taken at the beginning of the experiment but at the end was in underclothes 79.5 kilos. During the experiment he took a regular amount of muscular exercise each day.

TABLE 116.

Digestion experiment No. 195.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3296	Beef,	190	71	10.3	65	6	—	2	418
*	Deviled ham,	56	30	1.8	11	19	—	2	100
3298	Butter,	456	398	1.0	6	392	—	11	3607
3299	Milk,	3730	511	20.9	131	179	201	26	3156
3302	Bread,	1800	999	23.2	133	22	844	18	4559
3303	Graham crackers,	200	189	3.1	18	22	149	6	935
3304	Shredded wheat,	240	222	4.3	25	4	193	4	984
3305	Ginger snaps,	290	271	3.0	17	16	238	7	1254
3258	Milk sugar,	200	190	—	—	—	190	—	744
—	Sugar,	420	420	—	—	—	420	—	1663
	Total,	7582	3301	67.6	406	660	2235	76	17420
3306	Feces,	790	142	8.7	54	43	45	22	942
	Urine,	—	—	—	—	—	—	—	481
	Amount available,	—	3159	59.3	352	617	2190	54	15997
			%	%	%	%	%	%	%
	Coefficients of availability,		95.7	87.1	86.7	93.5	98.0	71.1	91.8

* Deviled ham used only in two meals, morning and noon of first day. Composition assumed from U. S. Dept. Agr. Office of Experiment Stations, Bul. 28.

During this experiment the subject eliminated 3726.6 grams urine, containing 62.1 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 16.9 grams; outgo in urine, 15.5 grams, and in feces, 2.2 grams; implying a loss of .8 gram nitrogen, corresponding to 5.0 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 196.

This experiment was a part of metabolism experiment No. 40, a work experiment with an excess of carbohydrates in the diet. It began with breakfast February 26, 1901, and continued four days. The subject, J. C. W., weighed in underclothes 78.8 kilos at the beginning and 77.8 kilos at the end of the experiment.

TABLE 117.

Digestion experiment No. 196.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3296	Beef, - - - - - -	240	89	13.1	82	7	—	2	528
3298	Butter, - - - - -	80	70	.2	1	69	—	2	632
3300	Milk, - - - - - -	1850	262	11.1	72	96	94	13	1707
3302	Bread, - - - - - -	2200	1221	28.4	163	26	1032	22	5572
3303	Graham crackers, - - -	400	378	6.2	36	44	298	12	1868
3304	Shredded wheat, - - -	320	295	5.8	33	5	257	5	1312
3305	Ginger snaps, - - - -	340	318	3.6	20	19	279	8	1468
3258	Milk sugar, - - - - -	400	380	—	—	—	380	—	1488
—	Sugar, - - - - - -	870	870	—	—	—	870	—	3445
	Total, - - - - -	6700	3883	68.4	407	266	3210	64	18020
3307	Feces, - - - - - -	618	123	8.6	53	22	48	19	728
	Urine, - - - - - -	—	—	—	—	—	—	—	573
	Amount available, - - -	—	3760	59.8	354	244	3162	45	16719
			%	%	%	%	%	%	%
	Coefficients of availability, -		96.8	87.4	87.0	91.7	98.5	70.3	92.8

During this experiment the subject eliminated 3329.6 grams urine, containing 67.3 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 17.1 grams; outgo in urine and perspiration, 17.1 grams, and in feces, 2.2 grams; implying a loss of 2.2 grams nitrogen, corresponding to 13.6 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 197.

This experiment formed a part of metabolism experiment No. 41, a work experiment with an excess of fat in the diet. It began March 2, 1901, and continued four days. The weight of the subject, J. C. W., in underclothes at the beginning of the experiment was 77.8 kilos and at the end 77.0 kilos.

TABLE 118.

Digestion experiment No. 197.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3296	Beef, - - - - - -	140	52	7.6	48	4	—	1	308
3298	Butter, - - - - - -	924	808	2.0	13	795	—	21	7308
3301	Milk, - - - - - -	5820	814	34.3	215	308	291	41	5302
3302	Bread, - - - - - -	1400	778	18.1	104	17	657	14	3546
3304	Shredded wheat, - - -	160	148	2.9	16	3	129	2	656
3305	Ginger snaps, - - -	240	224	2.5	14	13	197	6	1036
	Total, - - - - -	8684	2824	67.4	410	1140	1274	85	18156
3308	Feces, - - - - - -	687	122	5.8	36	45	41	28	925
	Urine, - - - - - -	—	—	—	—	—	—	—	631
	Amount available, - -	—	2702	61.6	374	1095	1233	57	16600
			%	%	%	%	%	%	%
	Coefficients of availability -		95.7	91.4	91.2	96.1	96.8	67.1	91.4

During this experiment the subject eliminated 6254.5 grams urine, containing 80.1 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 16.9 grams; outgo in urine, 20.3 grams, and in feces, 1.5 grams; implying a loss of 4.9 grams nitrogen, corresponding to 30.6 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 198.

This experiment, preliminary to metabolism experiment No. 43, began with breakfast March 25, 1901, and continued four days. The subject, J. C. W., weighed 79.2 kilos at the end of the experiment. During the period he took a considerable amount of muscular exercise daily. The diet contained an excess of fat.

TABLE 119.

Digestion experiment No. 198.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3309	Beef,	122.5	44	6.4	40	4	—	1	265
3318	Butter,	881.0	762	1.9	12	750	—	20	6821
3311	Milk,	5060.0	703	30.4	192	263	248	35	4478
3314	Bread,	1275.0	720	18.1	103	14	603	13	3326
3305	Ginger snaps,	240.0	224	2.5	14	13	197	6	1037
3304	Shredded wheat,	160.0	148	2.9	16	3	129	2	656
3321	Cereal coffee,	800.0	5	.1	—	—	5	1	27
*	Cocoa,	34.5	30	1.1	7	10	13	2	80
—	Sugar,	86.5	87	—	—	—	87	—	343
	Total,	8659.5	2723	63.4	384	1057	1282	80	17033
3315	Feces,	827.0	136	7.8	49	36	51	30	985
	Urine,	—	—	—	—	—	—	—	421
	Amount available,	—	2587	55.6	335	1021	1231	50	15627
			%	%	%	%	%	%	%
	Coefficients of availability,		95.0	87.7	87.3	96.6	96.0	62.5	91.7

* Composition taken from U. S. Dept. Agr. Office of Experiment Stations, Bul. No. 28.

During this experiment the subject eliminated 3685.1 grams urine, containing 65.3 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 15.9 grams; outgo in urine, 16.3 grams, and in feces, 2.0 grams; implying a loss of 2.4 grams nitrogen, corresponding to 15.0 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 199.

This experiment was a part of metabolism experiment No. 43, a work experiment with an excess of fat in the diet. It began with breakfast March 29, 1901, and continued four days. The weight of the subject, J. C. W., in underclothes was 79.2 kilos at the beginning of the experiment and 78.5 kilos at the end of the experiment.

TABLE 120.

Digestion experiment No. 199.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3309	Beef, - - - - - -	140	50	7.4	46	4	—	1	304
3310	Butter, - - - - -	980	846	1.9	12	834	—	26	7716
3312	Milk, - - - - - -	5420	786	33.6	212	298	276	38	4988
3314	Bread, - - - - -	1400	790	19.9	113	15	662	14	3652
3305	Ginger snaps, - - -	240	224	2.5	14	13	197	6	1036
3304	Shredded wheat, - - -	160	148	2.9	16	3	129	2	656
3321	Cereal coffee, - - -	4800	32	.5	3	—	29	5	164
—	Sugar, - - - - -	240	240	—	—	—	240	—	952
	Total, - - - - -	13380	3116	68.7	416	1167	1533	92	19468
3316	Feces, - - - - -	883	130	8.2	51	30	49	28	897
	Urine, - - - - -	—	—	—	—	—	—	—	588
	Amount available, - -	—	2986	60.5	365	1137	1484	64	17983
			%	%	%	%	%	%	%
	Coefficients of availability, -		95.8	88.0	87.8	97.4	96.8	69.6	92.3

During this experiment the subject eliminated 7885.7 grams urine, containing 75.0 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 17.1 grams; outgo in urine and perspiration, 19.1 grams, and in feces, 2.0 grams; implying a loss of 4.0 grams nitrogen, corresponding to 25.0 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 200.

This experiment formed a part of metabolism experiment No. 44, a work experiment with an excess of carbohydrates in the diet. It began April 2, 1901, and continued four days. The subject, J. C. W., weighed in underclothes 78.9 kilos at the beginning and 78.7 kilos at the end of the experiment.

TABLE 121.

Digestion experiment No. 200.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3309	Beef, - - - - -	240	86	12.6	79	7	—.	2	520
3310	Butter, - - - - -	80	69	.2	1	68	—	2	628
3313	Milk, - - - - -	1800	270	11.0	68	101	101	13	1692
3314	Bread, - - - - -	2200	1243	31.2	178	24	1041	22	5740
3305	Ginger snaps, - - -	340	318	3.6	20	19	279	8	1468
3304	Shredded wheat, - -	320	295	5.8	33	5	257	5	1312
3321	Cereal coffee, - - -	4800	32	.5	3	—	29	5	164
—	Sugar, - - - - -	1224	1224	—	—	—	1224	—	4848
3303	Graham crackers, - -	400	378	6.2	36	44	298	12	1868
3258	Milk sugar, - - -	400	380	—	—	—	380	—	1488
	Total, - - - - -	11804	4295	71.1	418	268	3609	69	19728
3317	Feces, - - - - -	802	131	10.3	65	16	50	19	762
	Urine, - - - - -	—	—	—	—	—	—	—	560
	Amount available, - -	—	4164	60.8	353	252	3559	50	18406
			%	%	%	%	%	%	%
	Coefficients of availability,		97.0	85.5	84.5	94.0	98.6	72.5	93.3

During this experiment the subject eliminated 8242.5 grams urine, containing 67.7 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 17.8 grams; outgo in urine and perspiration, 17.3 grams, and in feces, 2.6 grams; implying a loss of 2.1 grams nitrogen, corresponding to 13.1 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 201.

This experiment was a part of metabolism experiment No. 45, a work experiment with an excess of fat in the diet. It began with breakfast April 6, 1901, and continued one day. The subject weighed 78.8 kilos at the beginning and 78.3 kilos at the end of the experiment.

TABLE 122.

Digestion experiment No. 201.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3309	Beef, - - - - - -	35	12	1.8	11	1	—	—	76
3310	Butter, - - - - - -	245	211	.5	3	208	—	7	1929
3319	Milk, - - - - - -	1355	203	8.7	54	72	77	9	1240
3314	Bread, - - - - - -	350	198	5.0	28	4	166	4	913
3305	Ginger snaps, - - -	60	56	.6	4	3	49	—	259
3304	Shredded wheat, - - -	40	37	.7	4	1	32	1	164
3321	Cereal coffee, - - - -	1200	8	.1	1	—	7	1	41
—	Sugar, - - - - - -	60	60	—	—	—	60	—	238
	Total, - - - -	3345	785	17.4	105	289	391	22	4860
3320	Feces, - - - - - -	258	37	2.2	14	8	15	7	256
	Urine, - - - - - -	—	—	—	—	—	—	—	150
	Amount available, - -	—	748	15.2	91	281	376	15	4454
			%	%	%	%	%	%	%
	Coefficients of availability, -		95.3	87.4	86.7	97.2	96.2	68.2	91.7

During this experiment the subject eliminated 2233.9 grams urine, containing 18.9 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 17.4 grams; outgo in urine and perspiration, 19.3 grams, and in feces, 2.2 grams; implying a loss of 4.1 grams nitrogen, corresponding to 25.6 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 202.

This experiment was preliminary to metabolism experiment No. 46. It began with breakfast April 29, 1901, and continued four days. The subject, J. C. W., weighed in underclothes at the end of the experiment 79.6 kilos. He took a regular amount of muscular exercise each day during the period.

TABLE 123.

Digestion experiment No. 202.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3340	Beef, - - - - - -	140	51	7.5	47	4	—	1	307
3341	Butter, - - - - -	980	868	2.0	12	856	—	27	7922
3346	Bread, - - - - -	1400	791	17.8	101	22	668	13	3665
3305	Ginger snaps, - - - -	240	224	2.5	14	13	197	6	1037
3347	Shredded wheat, - - -	160	145	2.8	16	2	127	2	648
3342	Milk, - - - - - -	5470	766	33.9	213	279	274	44	4814
3348	Cereal coffee, - - -	4800	53	.5	5	—	48	—	221
—	Sugar, - - - - -	180	180	—	—	—	180	—	713
	Total, - - - - -	13370	3078	67.0	408	1176	1494	93	19327
3349	Feces, - - - - -	836	139	8.2	51	55	33	28	1010
	Urine, - - - - -	—	—	—	—	—	—	—	527
	Amount available, - -	—	2939	58.8	357	1121	1461	65	17790
			%	%	%	%	%	%	%
	Coefficients of availability, -		95.5	87.8	87.5	95.3	97.8	69.9	92.1

During this experiment the subject eliminated 7317.5 grams urine, containing 60.1 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 16.8 grams; outgo in urine, 15.0 grams, and in feces, 2.1 grams; implying a loss of .3 gram nitrogen, corresponding to 1.9 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 203.

This experiment was a part of metabolism experiment No. 46, a work experiment with an excess of fat in the diet. It began with breakfast May 3, 1901, and continued four days. The weight of the subject, J. C. W., in underclothes at the beginning was 79.6 kilos and at the end 79.7 kilos.

TABLE 124.

Digestion experiment No. 203.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3340	Beef, - - - - - -	140	51	7.6	47	4	—	1	308
3341	Butter, - - - - -	980	869	2.0	12	857	—	27	7924
3343	Milk, - - - - - -	5620	775	34.8	219	309	247	39	4832
3346	Bread, - - - - -	1400	791	17.8	101	22	668	13	3664
3305	Ginger snaps, - - -	240	224	2.5	14	13	197	6	1036
3347	Shredded wheat, - -	160	145	2.8	16	2	127	2	648
3348	Cereal coffee, - - -	4800	51	.5	3	—	48	—	220
—	Sugar, - - - - -	180	180	—	—	—	180	—	712
	Total, - - - - -	13520	3086	68.0	412	1207	1467	88	19344
3350	Feces, - - - - -	868	120	7.2	45	43	32	26	858
	Urine, - - - - -	—	—	—	—	—	—	—	576
	Amount available, - -	—	2966	60.8	367	1164	1435	62	17910
			%	%	%	%	%	%	%
	Coefficients of availability, -	—	96.1	89.4	89.1	96.4	97.8	70.5	92.6

During this experiment the subject eliminated 5446.6 grams urine, containing 63.6 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 17.0 grams; outgo in urine and perspiration, 16.1 grams, and in feces, 1.8 grams; implying a loss of .9 gram nitrogen, corresponding to 5.6 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 204.

This experiment was a part of metabolism experiment No. 47, a work experiment with an excess of carbohydrates in the diet. It began with breakfast May 7, 1901, and continued four days. The weight of the subject, J. C. W., in underclothes was 79.3 kilos at the beginning and 79.5 kilos at the end of the experiment.

TABLE 125.

Digestion experiment No. 204.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3340	Beef, - - - - - -	240	88	13.0	81	7	—	2	526
3341	Butter, - - - - -	80	71	.2	1	70	—	2	647
3344	Milk, - - - - - -	2000	282	12.4	78	100	104	14	1762
3346	Bread, - - - - -	2200	1242	27.9	158	35	1049	20	5760
3305	Ginger snaps, - - -	340	318	3.6	20	19	279	8	1470
3347	Shredded wheat, - - -	320	290	5.6	32	4	254	4	1296
3348	Cereal coffee, - - -	4800	51	.5	3	—	48	—	221
3258	Milk sugar, - - -	400	380	—	—	—	380	—	1488
—	Sugar, - - - - -	960	960	—	—	—	960	—	3801
3303	Graham crackers, - -	400	378	6.2	36	44	298	12	1869
	Total, - - - - -	11740	4060	69.4	409	279	3372	62	18840
3351	Feces, - - - - -	894	137	10.7	67	14	56	20	795
	Urine, - - - - -	—	—	—	—	—	—	—	579
	Amount available, - -	—	3923	58.7	342	265	3316	42	17466
			%	%	%	%	%	%	%
	Coefficients of availability, -		96.6	84.6	83.6	95.0	98.3	67.8	92.7

During this experiment the subject eliminated 6425.9 grams urine, containing 64.3 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 17.4 grams; outgo in urine and perspiration, 16.3 grams, and in feces, 2.7 grams; implying a loss of 1.6 grams nitrogen, corresponding to 10.0 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 205.

This experiment was part of metabolism experiment No. 48, a work experiment with an excess of fat in the diet. It began with breakfast May 11, 1901, and continued one day. The subject, J. C. W., weighed 79.5 kilos at the beginning and 78.8 kilos at the end.

TABLE 126.

Digestion experiment No. 205.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3340	Beef,	35	13	1.9	12	1	—	—	77
3341	Butter,	245	217	.5	3	214	—	7	1981
3345	Milk,	1405	198	8.7	55	67	76	10	1228
3346	Bread,	350	198	4.5	25	6	167	3	916
3305	Ginger snaps,	60	515	.6	3	3	49	1	259
3347	Shredded wheat,	40	37	.7	4	1	32	—	162
3348	Cereal coffee,	1200	13	.1	1	—	12	—	55
—	Sugar,	45	45	—	—	—	45	—	178
	Total,	3380	7716	17.0	103	292	381	21	4856
3352	Feces,	239	38	2.0	12	13	13	8	280
	Urine,	—	—	—	—	—	—	—	162
	Amount available,	—	738	15.0	91	279	368	13	4414
			%	%	%	%	%	%	%
	Coefficients of availability,		95.1	88.2	88.2	95.6	96.6	61.9	90.9

During this experiment the subject eliminated 1417.9 grams urine, containing 17.2 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 17.0 grams; outgo in urine, 17.4 grams, and in feces, 2.0 grams; implying a loss of 2.4 grams nitrogen, corresponding to 15.0 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 302.

This experiment, which was preliminary to metabolism experiment No. 49, began with breakfast March 23, 1902, and continued four days. During the experiment the subject performed a regular amount of muscular work every day. The weight of the subject, J. C. W., in underclothes was 80.4 kilos at the end of the experiment.

TABLE 127.

Digestion experiment No. 302.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3418	Butter,	80	71	.2	1	70	—	2	646
3423	Milk,	4000	516	21.6	136	164	216	28	3120
3419	Bread,	2200	1256	33.0	189	40	1027	29	5815
3420	Ginger snaps,	340	310	3.7	21	21	268	11	1449
3421	Shredded wheat,	320	288	5.9	34	4	250	6	1282
3422	Graham crackers,	400	376	5.5	31	46	299	11	1841
3258	Milk sugar,	400	380	—	—	—	380	—	1488
—	Sugar,	1440	1440	—	—	—	1440	—	5702
3425	Cereal coffee,	4800	34	.5	5	—	29	—	154
	Total,	13980	4671	70.4	417	345	3909	87	21497
3427	Feces,	887	143	9.9	62	19	62	24	792
	Urine,	—	—	—	—	—	—	—	547
	Amount available,	—	4528	60.5	355	326	3847	63	20158
			%	%	%	%	%	%	%
	Coefficients of availability,		97.0	85.9	85.1	94.5	93.7	72.4	93.8

During this experiment the subject eliminated 4603.3 grams urine, containing 63.9 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 17.6 grams; outgo in urine, 16.0 grams, and in feces, 2.5 grams; implying a loss of .9 gram nitrogen, corresponding to 5.6 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 303.

This experiment was a part of metabolism experiment No. 49, a work experiment with an excess of carbohydrates in the diet. It began with breakfast March 27, 1902, and continued three days. The subject, J. C. W., weighed in underclothes at the beginning of the experiment 80.4 kilos and at the end 80.7 kilos.

TABLE 128.

Digestion experiment No. 303.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3418	Butter,	60	54	.1	1	53	—	1	483
3424	Milk,	3000	429	19.5	123	150	156	21	2718
3419	Bread,	1650	943	24.7	142	30	771	22	4362
3420	Ginger snaps,	255	233	2.8	16	16	201	8	1086
3421	Shredded wheat,	240	216	4.4	25	3	188	5	960
3422	Graham crackers,	300	282	4.1	23	35	224	8	1380
3258	Milk sugar,	300	285	—	—	—	285	—	1116
—	Sugar,	1080	1080	—	—	—	1080	—	4278
3425	Cereal coffee,	3600	24	.4	2	—	22	—	114
	Total,	10485	3546	56.0	332	287	2927	65	16497
3427	Feces,	616	89	6.3	39	13	37	18	516
	Urine,	—	—	—	—	—	—	—	405
	Amount available,	—	3467	49.7	293	274	2890	47	15576
			%	%	%	%	%	%	%
	Coefficients of availability,		97.8	88.8	88.3	95.5	98.7	72.3	94.4

During this experiment the subject eliminated 7006.4 grams urine, containing 46.4 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 18.7 grams; outgo in urine and perspiration, 16.1 grams, and in feces, 2.1 grams; implying a gain of .5 gram nitrogen, corresponding to 2.9 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 304.

This experiment was a part of metabolism experiment No. 50, which began with breakfast March 30, 1902, and continued one day. It was planned to be a work experiment with an excess of fat in the form of butter in the diet, but as the digestive apparatus of the subject became deranged only a portion of the ration intended for the day was consumed. The weight of the subject, J. C. W., in underclothes was 80.7 kilos at the beginning and 79.8 kilos at the end.

TABLE 129.

Digestion experiment No. 304.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3418	Butter, - - - - -	94.6	84	.2	1	83	—	2	763
3424	Milk, - - - - -	925.0	132	6.0	38	46	48	6	838
3419	Bread, - - - - -	220.0	126	3.3	19	4	103	3	581
3420	Ginger snaps, - - -	60.0	55	.7	4	4	47	2	256
3421	Shredded wheat, - -	13.0	11	.2	.1	—	10	—	52
—	Sugar, - - - - -	22.8	23	—	—	—	23	—	90
3425	Cereal coffee, - - -	400.0	2	.1	—	—	2	—	13
—	Beef tea, - - - - -	294.2	2	.6	2	—	—	1	8
	Total, - - - - -	2029.6	435	11.1	65	137	233	14	2601
3429	Feces, - - - - -	114.8	18	1.2	7	4	7	4	128
	Urine, - - - - -	—	—	—	—	—	—	—	118
	Amount available, - -	—	417	9.9	58	133	226	10	2355
			%	%	%	%	%	%	%
	Coefficients of availability,	—	95.9	89.2	89.2	97.1	97.0	71.4	90.5

During this experiment the subject eliminated 1681.7 grams urine, containing 13.5 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 11.1 grams; outgo in urine and perspiration, 13.9 grams, and in feces, 1.2 grams; implying a loss of 4.0 grams nitrogen, corresponding to 25.2 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 305.

This experiment was preliminary to metabolism experiment No. 52, a work experiment with an excess of fat in the diet. It began with breakfast April 17, 1902, and continued four days. The weight of the subject, J. C. W., in underclothes at the end of the experiment was 79.8 kilos.

TABLE 130.

Digestion experiment No. 305.

Lab. No. sample.	Kind of Food.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3431	Butter,	180	158	.4	2	156	—	5	1460
3439	Cream,	3320	1026	13.3	83	800	143	17	8542
3435	Milk,	4000	500	21.6	132	168	200	32	3032
3432	Bread,	1760	983	25.7	146	26	811	18	4585
3420	Ginger snaps,	240	219	2.6	15	15	189	8	1023
3421	Shredded wheat,	160	144	2.9	17	2	125	3	641
—	Sugar,	180	180	—	—	—	180	—	713
3434	Cereal coffee,	4800	31	.4	2	—	29	—	134
	Total,	14640	3241	66.9	397	1167	1677	83	20130
3442	Feces,	556	102	5.3	33	23	46	23	744
	Urine,	—	—	—	—	—	—	—	532
	Amount available,	—	3139	61.6	364	1144	1631	60	18854
			%	%	%	%	%	%	%
	Coefficients of availability,		96.8	92.1	91.7	98.0	97.2	72.3	93.7

During this experiment the subject eliminated 3943.1 grams urine, containing 64.2 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 16.7 grams; outgo in urine, 16.1 grams, and in feces, 1.3 grams; implying a loss of .7 gram nitrogen, corresponding to 4.4 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 306.

This experiment, a part of metabolism experiment No. 52, a work experiment with an excess of fat in the diet, began with breakfast April 21, 1902, and continued three days. The weight of the subject, J. C. W., in underclothes was 79.8 kilos at the beginning and 79.4 kilos at the end.

TABLE 131.

Digestion experiment No. 306.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3431	Butter,	135	119	.3	2	117	—	4	1095
3440	Cream,	3380	994	13.8	88	727	179	20	7847
3436	Milk, whole,	2550	346	15.3	94	125	127	20	2162
3432	Bread,	1320	738	19.3	110	20	608	13	3439
3420	Ginger snaps,	180	164	1.9	11	11	142	6	767
3421	Shredded wheat,	120	109	2.2	13	2	94	2	481
—	Sugar,	135	135	—	—	—	135	—	535
3434	Cereal coffee,	3600	23	.3	1	—	22	—	101
	Total,	11420	2628	53.1	319	1002	1307	65	16427
3443	Feces,	703	89	4.7	30	18	43	23	684
	Urine,	—	—	—	—	—	—	—	383
	Amount available,	—	2539	48.4	289	984	1264	42	15360
			%	%	%	%	%	%	%
	Coefficients of availability,	—	96.6	91.1	90.6	98.2	96.7	64.6	93.5

During this experiment the subject eliminated 5421.5 grams urine, containing 48.0 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 17.7 grams; outgo in urine and perspiration, 16.4 grams, and in feces, 1.6 grams; implying a loss of .3 gram nitrogen, corresponding to 2.1 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 307.

This experiment, forming part of metabolism experiment No. 53, a work experiment with an excess of carbohydrates in the diet, began with breakfast April 24, 1902, and continued three days. The weight of the subject, J. C. W., in underclothes was 79.4 kilos at the beginning and 80.2 kilos at the end.

TABLE 132.

Digestion experiment No. 307.

Lab. No. sample.	Kind of Food.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3431	Butter, - - - - -	60	53	.1	1	52	—	2	486
3437	Milk, - - - - - -	3000	402	17.4	108	153	141	24	2514
3433	Bread, - - - - -	1650	947	24.8	140	28	779	17	4395
3420	Ginger snaps, - - -	255	233	2.8	16	16	201	8	1086
3422	Graham crackers, - -	300	282	4.1	23	35	224	8	1380
3421	Shredded wheat, - - -	240	216	4.4	25	3	188	5	960
—	Sugar, - - - - -	1110	1110	—	—	—	1110	—	4395
3258	Milk sugar, - - -	300	285	—	—	—	285	—	1116
3434	Cereal coffee, - - -	3600	23	.2	2	—	21	—	102
	Total, - - - - -	10515	3551	53.8	315	287	2949	64	16434
3444	Feces, - - - - -	761	106	7.0	44	19	43	20	654
	Urine, - - - - -	—	—	—	—	—	—	—	383
	Amount available, - -	—	3445	46.8	271	268	2906	44	15400
			%	%	%	%	%	%	%
	Coefficients of availability, -		97.0	87.0	86.0	93.4	98.5	68.8	93.7

During this experiment the subject eliminated 3621.4 grams urine, containing 44.6 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 17.9 grams; outgo in urine and perspiration, 15.4 grams, and in feces, 2.3 grams; implying a gain of .2 gram nitrogen, corresponding to 1.3 grams protein.

DETAILS OF DIGESTION EXPERIMENT NO. 308.

This experiment which forms a part of both metabolism experiments 54 and 55, began with breakfast April 27, 1902, and continued four days. These were both work experiments with an excess of fat in the diet, but No. 55 comprised one day of work that was much harder than usual, and continued at least twice as long. The weight of the subject, J. C. W., in underclothes was 80.2 kilos at the beginning and 76.4 kilos at the end of the experiments.

TABLE 133.

Digestion experiment No. 308.

Lab. No. sample.	KIND OF FOOD.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion (determined).
		Gms	Gms	Gms	Gms	Gms	Gms	Gms	Cal.
3431	Butter, - - - - -	180	158	.4	2	156	—	5	1460
3441	Cream, - - - - -	4205	1320	19.3	122	971	227	25	10395
3438	Milk, whole, - - -	3400	493	20.8	129	197	167	27	2992
3433	Bread, - - - - -	1760	1011	26.4	150	30	831	18	4688
3420	Ginger snaps, - - -	240	219	2.6	15	15	189	8	1024
3421	Shredded wheat, - - -	160	144	3.0	17	2	125	3	640
—	Sugar, - - - - -	180	180	—	—	—	180	—	712
3434	Cereal coffee, - - -	4800	31	.3	2	—	29	—	136
—	Beef tea, - - - - -	300	1	.4	1	—	—	—	6
	Total, - - - - -	15225	3557	73.2	438	1371	1748	86	22053
3445	Feces, - - - - -	829	132	6.8	42	28	62	32	969
	Urine, - - - - -	—	—	—	—	—	—	—	540
	Amount available, - -	—	3425	66.4	396	1343	1686	54	20544
			%	%	%	%	%	%	%
	Coefficients of availability, -		96.3	90.7	90.4	98.0	96.5	62.8	93.2

During this experiment the subject eliminated 7633.1 grams urine, containing 67.2 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 18.3 grams; outgo in urine and perspiration, 17.4 grams, and in feces, 1.7 grams; implying a loss of .8 gram nitrogen, corresponding to 5.0 grams protein.

The results of the digestion experiments are summarized in the following table.

TABLE 134.

Summary of results of digestion experiments.

Digestion experiment No.	Metabolism experiment No.	SUBJECT AND CHARACTER OF EXPERIMENT.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
		PRELIMINARY PERIOD.					
		Rest experiments.	%	%	%	%	%
37	5	E. O., - - - - - - - -	92.6	94.0	98.0	75.2	90.0
43	8	E. O., - - - - - - - -	91.0	94.4	97.4	73.1	89.9
45	9	E. O., - - - - - - - -	90.8	92.1	95.8	73.0	88.5
76	13	E. O., - - - - - - - -	96.8	96.3	98.9	86.5	93.1
78	14	E. O., - - - - - - - -	92.0	93.4	98.5	79.1	91.1
		Average (5) E. O., - - - -	**92.6**	**94.0**	**97.7**	**77.4**	**90.5**
147	25	J. F. S., - - - - - - - -	93.9	96.8	97.7	69.8	91.7
149	26	J. F. S., fat diet, - - - - -	88.6	94.1	95.7	44.4	87.5
		Average (2) J. F. S., - - -	**91.3**	**95.4**	**96.7**	**57.1**	**89.6**
189	35	J. C. W., - - - - - - - -	93.1	96.4	98.4	77.6	87.4
		Average (8) E. O., J. F. S., J. C. W.,	**92.4**	**94.7**	**97.6**	**72.3**	**89.9**
		Work experiments.					
39	6	E. O., - - - - - - - -	89.9	95.3	97.6	72.6	91.2
49	11	E. O., - - - - - - - -	90.3	93.2	97.8	74.4	91.4
		Average (2) E. O., - - - - -	**90.1**	**94.2**	**97.7**	**73.5**	**91.3**
153	29	J. F. S., carbohydrate diet, - -	94.3	96.4	98.7	76.3	93.2
157	32	J. F. S., fat diet, - - - - -	90.4	95.7	96.8	69.9	91.0
		Average (2) J. F. S., - - - -	**92.3**	**96.1**	**97.8**	**73.1**	**92.1**
192	37	J. C. W., carbohydrate diet, - -	90.6	96.6	98.6	80.0	90.7
195	40	J. C. W., carbohydrate diet, - -	86.7	93.5	98.0	71.1	91.8
198	43	J. C. W., fat diet, - - - - -	87.3	96.6	96.0	62.5	91.7
202	46	J. C. W., fat diet, - - - - -	87.5	95.3	97.8	69.9	92.1
302	49	J. C. W., carbohydrate diet, - -	85.1	94.5	93.7	72.4	93.8
305	52	J. C. W., fat diet, - - - - -	91.7	98.0	97.2	72.3	93.7
		Average (6) J. C. W., - - - -	**88.2**	**95.8**	**96.9**	**71.4**	**92.3**
		Average (10) E. O., J. F. S., J. C. W.,	**89.4**	**95.5**	**97.2**	**72.1**	**92.1**
		Average all (18) preliminary period,	**90.7**	**95.1**	**97.4**	**72.2**	**91.1**
		CALORIMETER PERIOD.					
		Rest experiments.					
38	5	E. O., - - - - - - - -	91.2	93.9	97.7	75.3	89.8
44	8	E. O., - - - - - - - -	93.9	95.6	98.2	78.7	90.7
46	9	E. O., - - - - - - - -	93.4	93.9	96.5	78.9	89.3
77	13	E. O., - - - - - - - -	93.9	93.2	98.1	76.4	90.2
79	14	E. O., - - - - - - - -	94.4	95.5	98.9	86.2	91.1
84	23	E. O., - - - - - - - -	94.3	94.7	97.8	70.0	90.0
85	24	E. O., carbohydrate diet, - - -	93.3	93.7	98.5	74.0	91.8
		Average (7), - - - - - -	**93.5**	**94.4**	**98.0**	**77.1**	**90.4**
148	25	J. F. S., fat diet, - - - - -	94.4	97.4	97.4	71.4	91.1
150	26	J. F. S., fat diet, - - - - -	92.8	97.2	97.3	66.0	90.6
152	28	J. F. S., carbohydrate diet, - -	92.0	90.1	98.6	69.0	90.4
		Average (3), - - - - - -	**93.1**	**94.9**	**97.8**	**68.8**	**90.7**
190	35	J. C. W., - - - - - - - -	92.1	95.3	97.8	69.4	90.3
		Average (11) E. O., J. F. S., J. C. W.,	**93.2**	**94.6**	**97.9**	**74.1**	**90.5**

TABLE 134.—*(Continued.)*

Digestion experiment No.	Metabolism experiment No.	Subject and Character of Experiment.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
		CALORIMETER PERIOD. *Work experiments.*	%	%	%	%	%
40	6	E. O.,	91.8	96.9	98.3	79.8	92.8
50	11	E. O.,	88.4	93.0	97.5	71.8	90.9
		Average (2),	**90.1**	**94.9**	**97.9**	**75.8**	**91.9**
154	29	J. F. S., carbohydrate diet,	94.5	97.2	98.7	80.0	93.5
156	31	J. F. S., fat diet,	94.8	98.3	98.2	80.4	93.7
158	32	J. F. S., fat diet,	92.5	97.1	97.4	73.2	92.5
160	34	J. F. S., carbohydrate diet,	92.4	95.0	98.4	68.6	92.8
		Average (4),	**93.5**	**96.9**	**98.2**	**75.6**	**93.1**
193	37	J. C. W., carbohydrate diet,	90.1	94.2	98.8	69.4	93.0
194	38	J. C. W., fat diet,	92.7	96.7	97.4	67.5	91.7
196	40	J. C. W., carbohydrate diet,	87.0	91.7	98.5	70.3	92.8
197	41	J. C. W., fat diet,	91.2	96.1	96.8	67.1	91.4
199	43	J. C. W., fat diet,	87.8	97.4	96.8	69.6	92.3
200	44	J. C. W., carbohydrate diet,	84.5	94.0	98.6	72.5	93.3
201	45	J. C. W., fat diet,	86.7	97.2	96.2	68.2	91.7
203	46	J. C. W., fat diet,	89.1	96.4	97.8	70.5	92.6
204	47	J. C. W., carbohydrate diet,	83.6	95.0	98.3	67.8	92.7
205	48	J. C. W., fat diet,	88.2	95.6	96.6	61.9	90.9
303	49	J. C. W., carbohydrate diet,	88.3	95.5	98.7	72.3	94.4
304	50	J. C. W.,	89.2	97.1	97.0	71.4	90.5
306	52	J. C. W., fat diet,	90.6	98.2	96.7	64.6	93.5
307	53	J. C. W., carbohydrate diet,	86.0	93.4	98.5	68.8	93.7
308	54–55	J. C. W., fat diet,	90.4	98.0	96.5	62.8	93.2
		Average (15),	**88.4**	**95.8**	**97.5**	**68.3**	**92.5**
		Average (21) E. O., J. F. S., J. C. W.,	**89.5**	**95.9**	**97.7**	**70.4**	**92.6**
		Average all (32) calorimeter period,	**90.8**	**95.5**	**97.8**	**71.7**	**91.9**
		Av. all (50) prelim. and calor. periods,	**90.8**	**95.3**	**97.6**	**71.9**	**91.6**

The digestion experiments are arranged here in two groups, according to whether they were carried on during the preliminary period, while the subject was still going about outside the apparatus, or during the period of the metabolism experiment while the subject was within the respiration calorimeter. Under these two main divisions the results are still further classified as rest and work experiments, which are given separately for each subject. The experiments designated by "carbohydrate diet" and "fat diet" were those in which large quantities of fat or carbohydrates were used, as explained in a later paragraph.

It will be observed that there is not a preliminary experiment for each metabolism experiment. The reason for this is that the metabolism experiments following No. 14 were made in series, with a preliminary period for the series rather than for each experiment; that is, there was a preliminary digestion period, after which the subject entered the respiration calorimeter and remained there for nine to twelve days consecutively, and this latter period was divided into two or more metabolism experiments, each with its digestion experiment. This explains why the total number of experiments for the calorimeter period is larger than that for the preliminary period.

Effect of confinement within the calorimeter upon availability.— The averages of the results of experiments within the calorimeter are compared with those of experiments outside the calorimeter in the table below. The rest experiments and the work experiments are given separately for the different subjects.

Comparison of results of experiments during preliminary periods with those of experiments during calorimeter periods.

	Protein.	Fat.	Carbohydrates.	Energy.
Rest experiments.	%	%	%	%
E. O., preliminary period (average of 5),	92.6	94.0	97.7	90.5
E. O., calorimeter period (average of 7),	93.5	94.4	98.0	90.4
J. F. S., preliminary period (average of 2),	91.3	95.4	96.7	89.6
J. F. S., calorimeter period (average of 3),	93.1	94.9	97.8	90.7
J. C. W., preliminary period (1),	93.1	96.4	98.4	87.4
J. C. W., calorimeter period (1),	92.1	95.3	97.8	90.3
Average 8 preliminary,	**92.4**	**94.7**	**97.6**	**89.9**
Average 11 calorimeter,	**93.2**	**94.6**	**97.9**	**90.5**
Work experiments.				
E. O., preliminary period (average of 2),	90.1	94.2	97.7	91.3
E. O., calorimeter period (average of 2),	90.1	94.9	97.9	91.9
J. F. S., preliminary period (average of 2),	92.3	96.1	97.8	92.1
J. F. S., calorimeter period (average of 4),	93.5	96.9	98.2	93.1
J. C. W., preliminary period (average of 6),	88.2	95.8	96.9	92.3
J. C. W., calorimeter period (average of 15),	88.4	95.8	97.5	92.5
Average 10 preliminary,	**89.4**	**95.5**	**97.2**	**92.1**
Average 21 calorimeter,	**89.5**	**95.9**	**97.7**	**92.6**

Apparently the sojourn within the calorimeter had little influence upon the digestibility of the diet. In comparing the results of the different experiments with the same subject, given in Table 134 above, it will be noticed that in some instances the coefficients were smaller, and in others larger in the calorimeter than in the preliminary period. In a few of the experiments the differences were quite appreciable, but in most of them they were small; and generally the differences between preliminary and calorimeter periods were smaller than those between two experiments in the same period, as will be seen by comparing the agreement of the averages in the above table and that of individual experiments of Table 134. The averages for the preliminary and calorimeter periods for the same subject were reasonably close. In the averages of all the preliminary experiments with all these subjects and all the calorimeter experiments with all the subjects, the differences are practically negligible. That is to say, so far as the utilizing of the food was concerned, it made practically no difference whether the subject was confined in a small room or was free to move about without limit.

Influence of muscular work upon availability.—The experiments in which the amount of muscular activity was least were the rest experiments within the calorimeter. In these the subjects remained as quiet as they could during the greater part of the time; their muscular exercise consisted chiefly of that involved in writing, taking observations of body temperature, etc., caring for food and excreta, and folding or unfolding the chair, table or bed as needed. In later experiments the amount of work was even smaller than in the earlier ones, because the subjects dressed only in underclothing, to avoid the expenditure of energy involved in putting on and taking off their outer garments. The total amount of work performed each day during the rest experiments within the calorimeter was far less than that of a man at any ordinary sedentary occupation.

During the days preliminary to the rest experiments within the calorimeter the subjects avoided all unnecessary exertion, but were engaged in their usual occupations, which with E. O.

and J. F. S. was that of the chemical laboratory, and with J. C. W. was that of a college student. It was not arduous for any of them, but involved more or less walking or standing, so that the amount of muscular exercise was greater than during the otherwise similar experiments within the calorimeter. In these the total amount of work done in a day would be at largest equivalent to what might be understood as that of a man at "light muscular work."

The exercise of the subjects during the days preliminary to the work experiments consisted of that of their usual occupation and in addition the labor involved in pedalling the stationary bicycle or a "home trainer" a certain length of time within doors, or in long walks or bicycle rides over country roads. The total amount of energy expended daily during these experiments would doubtless be equivalent to that of a man at "light to moderate muscular work."

In the work experiments within the calorimeter the subjects performed all the duties required of them in the rest experiments, and besides spent eight hours each day operating a bicycle arranged as an ergometer, for measuring the amount of work done. This was perhaps nearly equivalent to that of a man at "hard work." In the last day of the last experiment (No. 308) included in this report the subject, J. C. W., worked much harder than ordinarily and continued the work for sixteen hours.

The figures in Table 134 are arranged so that the results with each subject during the different kinds of experiment may be easily compared. From these it will be observed that in some cases, with the same subject, the coefficients of availability are larger where the work is less, and in other cases they are smaller. The differences between the experiments with different amounts of work, however, are generally no larger than those between different experiments with the same quantity of exercise. Compare, for instance, the results in metabolism experiment No. 9 with those in the period preliminary to No. 9, and then compare the results in experiments Nos. 9 and 13 in the preliminary period, or Nos. 5 and 13 in

the calorimeter period. In the majority of cases, however, the variations of the individual experiments of one kind with any subject from the average of all the experiments of that kind with the same subject are small. In like manner the averages of the same kind of experiments vary so little with the different subjects that all the experiments of one kind may be arranged for all the subjects together, and the averages of the different kinds of experiments may be compared as follows:

Comparison of averages of results of experiments with different degrees of muscular activity.

	Protein.	Fat.	Carbohydrates.	Energy.
	%	%	%	%
Rest experiments within the calorimeter,	93.2	94.6	97.9	90.5
Rest experiments outside of calorimeter,	92.4	94.7	97.6	89.9
Work experiments outside of calorimeter,	89.4	95.5	97.2	92.1
Work experiments within the calorimeter,	89.5	95.9	97.7	92.6

These results indicate that the amount of work performed had no effect upon the availability of the nutrients of the diet. The average coefficients of availability of carbohydrates are very close for all four kinds of experiments; those for fat are a very little larger in the work experiments than in the rest experiments; those for protein are quite noticeably smaller in the work experiments. The latter difference is due, however, not to the increase in the amount of work, but to a decrease in the amount of animal protein in the diet. In the majority of the work experiments the quantities of vegetable foods were increased, and the proportion of the protein of the diet supplied in vegetable foods was much larger than in the rest experiments. Because of the lower digestibility of the vegetable protein, it would be expected that the coefficients found for the whole diet would be smaller than in the experiments in which the proportion of animal protein in the diet was larger. This is especially true of the larger part of the experiments following No. 195. By referring to Table 134, it will be observed that these are the ones in which the coefficients of availability of protein are lowest.

Effect of fat or carbohydrates upon availability.—The results of the different experiments in which sugar or fat predominated are grouped by subjects in the following table:

TABLE 135.

Comparison of the results of experiments with sugar diet and with fat diet.

Digestion experiment No.	Metabolism experiment No.	SUBJECT AND KIND OF EXPERIMENT.	Protein.	Fat.	Carbohydrates.	Ash.	Fuel value.
			%	%	%	%	%
147	P 25	J. F. S., rest, fat diet, - - - -	93.9	96.8	97.7	69.8	91.7
148	25	J. F. S., rest, fat diet, - - - -	94.4	97.4	97.4	71.4	91.1
149	P 26	J. F. S., rest, fat diet, - - - -	88.6	94.1	95.7	44.4	87.5
150	26	J. F. S., rest, fat diet, - - - -	92.8	97.2	97.3	66.0	90.6
156	P 32	J. F. S., work, fat diet, - - - -	90.4	95.7	96.8	69.9	91.0
157	31	J. F. S., work, fat diet, - - - -	94.8	98.3	98.2	80.4	93.7
158	32	J. F. S., work, fat diet, - - - -	92.5	97.1	97.4	73.2	92.5
		Average (7) J. F. S., - - - -	**92.5**	**96.7**	**97.2**	**67.9**	**91.2**
194	38	J. C. W., work, fat diet, - - - -	92.7	96.7	97.4	67.5	91.7
197	41	J. C. W., work, fat diet, - - - -	91.2	96.1	96.8	67.1	91.4
198	P 43	J. C. W., work, fat diet, - - - -	87.3	96.6	96.0	62.5	91.7
199	43	J. C. W., work, fat diet, - - - -	87.8	97.4	96.8	69.6	92.3
201	45	J. C. W., work, fat diet, - - - -	86.7	97.2	96.2	68.2	91.7
202	P 46	J. C. W., work, fat diet, - - - -	87.5	95.3	97.8	69.9	92.1
203	46	J. C. W., work, fat diet, - - - -	89.1	96.4	97.8	68.2	91.7
205	48	J. C. W., work, fat diet, - - - -	88.2	95.6	96.6	61.9	90.9
305	52	J. C. W., work, fat diet, - - - -	91.7	98.0	97.2	72.3	93.7
308	54–55	J. C. W., work, fat diet, - - - -	90.4	98.0	96.5	62.8	93.2
		Average (10) J. C. W., - - -	**89.3**	**96.7**	**96.9**	**67.0**	**92.0**
		Average (17) J. F. S., J. C. W., -	**90.6**	**96.7**	**97.0**	**67.4**	**91.7**
85	24	E. O., rest, carbohydrate diet, - -	93.3	93.7	98.5	74.0	91.8
152	28	J. F. S., rest, carbohydrate diet, -	92.0	90.1	98.6	69.0	90.4
153	P 29	J. F. S., work, carbohydrate diet, -	94.3	96.4	98.7	76.3	93.2
154	29	J. F. S., work, carbohydrate diet, -	94.5	97.2	98.7	80.0	93.5
160	34	J. F. S., work, carbohydrate diet, -	92.4	95.0	98.4	68.6	92.8
		Average (4) J. F. S., - - - -	**93.3**	**94.7**	**98.6**	**73.5**	**92.5**
192	P 37	J. C. W., work, carbohydrate diet, -	90.6	96.6	98.6	80.0	90.7
193	37	J. C. W., work, carbohydrate diet, -	90.1	94.2	98.8	69.4	93.0
195	P 40	J. C. W., work, carbohydrate diet, -	86.7	93.5	98.0	71.1	91.8
196	40	J. C. W., work, carbohydrate diet, -	87.0	91.7	98.5	70.3	92.8
200	44	J. C. W., work, carbohydrate diet, -	84.5	94.0	98.6	72.5	93.3
204	47	J. C. W., work, carbohydrate diet, -	83.6	95.0	98.3	67.8	92.7
302	P 49	J. C. W., work, carbohydrate diet, -	85.1	94.5	93.7	72.4	93.8
303	49	J. C. W., work, carbohydrate diet, -	88.3	95.5	98.7	72.3	94.4
307	53	J. C. W., work, carbohydrate diet, -	86.0	93.4	98.5	68.8	93.7
		Average (9) J. C. W., - - - -	**86.9**	**94.3**	**98.0**	**71.6**	**92.9**
		Average (14) E. O., J. F. S., J. C. W.,	**89.1**	**94.3**	**98.2**	**72.3**	**92.7**

It has been commonly supposed that if the quantity of any ingredient of the diet is very large the body will avail itself of a smaller proportion than if the total quantity consumed is smaller. In a number of the metabolism experiments (those designated by "fat diet" and "carbohydrate diet" in Table 134) the purpose was to study the value of different nutrients as sources of energy to the body, and especially to compare fat and sugar in this respect. To do this, the diet was arranged so that the amount of one of these would be relatively large and that of the other relatively small. In the earlier experiments this was accomplished by taking out of the diet in some cases a certain quantity of fat, and substituting for it enough of sugar to supply the energy removed, or, in other cases, removing sugar or other carbohydrates from the diet and substituting fat. In later experiments, more particularly those with J. C. W., a definite basal ration, with a moderate quantity of both fat and carbohydrates, was used, and to this was added a decidedly large quantity of sugar in some cases and a corresponding amount of fat in others. In other words, in order to make the comparative tests of fat and sugar effective, the quantities of either were in the earlier experiments somewhat larger, and in the later experiments very much larger than in the ordinary diet. In all cases where sugar and fat were thus compared the attempt was made to have the two diets as nearly equivalent in available energy as practicable.

In the experiments with J. F. S. on a fat diet, the lowest coefficient of availability of fat was 94.1, and the highest 98.3; in the average of seven experiments it was 96.7. In similar experiments with J. C. W., the lowest coefficient was 95.3, and the highest 98.0, the average of ten experiments being also 96.7.

In the experiments with J. F. S. on a carbohydrate diet, the lowest coefficient of availability of carbohydrates was 98.4, and the highest 98.7; in the average of four experiments it was 98.6. In similar experiments with J. C. W., the lowest coefficient was 93.7, but this was the only case in which it was below 98.0; the highest was 98.8, and the average of nine experiments it was 98.0. The averages of all the experiments with "fat diet" and all those with "carbohydrate diet" with both subjects are summarized below, in comparison with the

average of the results of eighteen experiments with the same two and one other subject, in which each of these nutrients, though varying in different experiments, was in no case especially large.

Comparison of results of "fat diet" and "carbohydrate diet" with those of ordinary diet.

	Protein.	Fat.	Carbohydrates.	Energy.
	%	%	%	%
Average 14 experiments with carbohydrate diet, - - - - - -	89.1	94.3	98.2	92.7
Average 17 experiments with fat diet, -	90.6	96.7	97.0	91.7
Average 18 experiments with ordinary diet, - - - - - -	92.4	94.5	97.9	90.5

The average coefficient for carbohydrates is very slightly in favor of the diet with the larger quantity; for practical purposes it is the same as that for the ordinary diet. In the case of the fat the difference was more noticeably in favor of the diet with the large quantity; that is to say, where the quantity of fat was largest in these experiments the coefficient of availability was greatest. The protein in the diets with the large quantities of fat and carbohydrates was less available than in the ordinary diet. This is due more probably to what has already been pointed out, namely, that the proportion of vegetable protein in the diet was much larger in the former experiments, than to any effect of the increase in the quantity of one nutrient in the diet upon the availability of the others. In fact, there does not appear to have been any such effect; the availability of the fat in the ration with the large amount of carbohydrates was almost identical with that in the ordinary diet; while the availability of the carbohydrates was very nearly as large in the diet with the large quantities of fat as in the ordinary ration.

In a previous report of this station* an attempt was made to establish factors for the digestibility of the nutrients of mixed diet which could be put into general use. The results of some of the experiments given in the present article were made use of there, together with results of a number of experiments

* Report for 1899, p. 86.

made elsewhere. The factors for availability of the nutrients of total food of mixed diet suggested at that time are here compared with the average of the results of all the experiments included in the present report. The former are given in round numbers.

	Protein.	Fat.	Carbohydrates.
	%	%	%
Proposed factors, - - - - -	92.0	95.0	97.0
Average of results here given, - - -	90.8	95.3	97.6

SUMMARY AND CONCLUSION.

The purpose of the digestion experiments here reported was to find what proportions of the protein, fats, carbohydrates, and energy of ordinary mixed diet, when eaten by healthy men, were made available to the body. The results for the different nutrients were found by comparing the quantity of each in the original food material with the quantity of the corresponding ingredient in the intestinal excreta. In the case of the energy, that of the unoxidized material of the urine was also taken into account. The results expressed in percentages are taken as the coefficients of availability.

These factors are frequently called coefficients of digestibility. It is a common practice to consider the solid excreta as representing the indigestible portion of the food. This, however, is not quite accurate, because the feces include, besides the undigested residues of food, the residues of digestive juices, and other materials, so that the amounts of ingredients in the feces are larger than those of the portion of the food which escapes digestion, and the proportions of digestible nutrients when calculated from total food and total feces are thus made too small. On the other hand, the total material of the feces does represent that which was unavailable to the body for the two chief purposes of nutrition, the building of tissue and the yielding of energy. It is therefore more correct to apply the term availability to the difference between food and feces. But while this term is here preferred, the term digestibility may also be used in deference to common custom; so long as the meaning is clearly understood it is of little importance which term is employed.

Fifty digestion experiments are here reported. These were made with three different subjects, all young, active, healthy men, whose digestive powers were believed to be unimpaired. The individual experiments were generally three or four days in length, though a few were only one day and one was eight days. Eighteen of the experiments were carried on while the subjects were outside the calorimeter, and thirty-two formed part of the metabolism experiments with the subjects in the respiration chamber. The amounts of (external) muscular work performed by the subjects ranged in different experiments from almost none to hard work eight hours a day, and in one experiment sixteen hours. The diet was simple, and contained a number of common food materials, both animal and vegetable. In eighteen of the studies the quantities of the different nutrients were about the same as in ordinary diet. In seventeen experiments the diet contained large quantities of fat, and in fourteen large quantities of carbohydrates, though the energy in these cases was not greater than was required to satisfy the needs of the body under the conditions of the experiments.

No effect of individuality upon the availability of the nutrients of the diet is evident. With each subject the range of variation in the results of similar experiments is much wider than the differences between the averages of similar experiments with different subjects.

If the sojourn within the calorimeter had any influence upon the availability of the diet, it was to improve it very slightly in some cases; while in others there was no apparent effect. The individual experiments show considerable variation in the results inside and outside the calorimeter, the availability being with the same subject sometimes larger and sometimes smaller inside the calorimeter than outside. Comparing the averages of the results for all the preliminary periods for each subject with those for the calorimeter periods, the coefficients were slightly larger with E. O. and J. F. S. during the latter period, but with J. C. W. the average results were practically the same for the experiments within the calorimeter as for those outside.

Increasing the quantity of either carbohydrates or fat above those common in the ordinary diet had no effect upon the availability of the other nutrients of the diet, while the availability of the fat or the carbohydrates in the experiments in which either

was used in large quantities was as large as, or larger than in the experiments in which the quantities were more nearly like those in the ordinary diet.

In these experiments more or less severe muscular work had no apparent effect upon the availability of the different nutrients of the diet. It made practically no difference whether the men were as quiet as possible, or were engaged in very light, or moderate, or severe muscular work, the proportions of unavailable material rejected by the intestine were no larger in one case than in the other. That is to say, so far as the using up of the nutrients of the food was concerned, the amount of muscular exercise made no appreciable difference.

Although the number of experiments is large, there were not enough of them, nor were they made with enough different subjects, nor were there enough kinds and combinations of food materials to warrant final conclusions as to the average amounts of nutrients digested from ordinary diet by healthy men in general; at the same time the agreement of the results with each other and with those of other experiments implies that the general average is not very far from an indication of the availability of the nutrients of mixed diet when eaten by people in good health under conditions which obtain in the United States. Accordingly it would seem that we shall not be very far out of the way in assuming that the coefficients of availability of the nutrients of mixed diet are: For protein, 92 per cent.; for fat, 95 per cent., and for carbohydrates, 97 per cent. That is to say, these figures may be taken as representing very nearly the proportions which are actually available to the body for the building of tissue and the yielding of energy.

It is to be borne in mind, however, that these factors depend considerably upon the proportions of animal and vegetable foods in the diet, as the availability of the nutrients is different in different materials. Thus, the protein of animal foods, like meat and milk, is more completely digested and utilized than that of most vegetable foods, like beans or potatoes. The availability of the protein of mixed diet will therefore vary according as it contains a larger or smaller proportion of animal food. Roughly speaking, however, about 95-96 per cent. of the total organic matter and 91-92 per cent. of the total energy of mixed diet will be available. To put it in another way, the body rejects about 5 per cent. of the nutrients and about 9 per cent. of the energy of its food.

METEOROLOGICAL OBSERVATIONS AT STORRS AND GENERAL WEATHER AND CROP REVIEW.

REPORTED BY C. S. PHELPS.

The Station equipment at Storrs for meteorological observations consists of the ordinary instruments for determining temperatures, pressure of the air, humidity, rainfall and snowfall, similar to those in use by the Weather Bureau of the United States Department of Agriculture. A summary of the observations made at Storrs is given in Table 137.

In addition to the records made at Storrs, the rainfall for the summer season (May 1 to October 31) was recorded by eight farmers in different parts of the State in coöperation with the Station. These measurements are given in Table 136, together with those supplied by thirteen stations of the New England Meteorological Society.

The total precipitation for the year as recorded at Storrs was 66.5 inches. This is the heaviest annual precipitation since the Station began observations in 1888, being about 19.5 inches above the average (47.0 inches) for thirteen years. The rainfall was exceptionally heavy during January, March, April and May and again in July and December. The early part of the season was so wet and cool that farm work was greatly delayed and much seed rotted in the ground. The seasons for planting, cultivating and haying were crowded upon each other so closely that some kinds of farm work had to be neglected in favor of the most important. The hay crop was generally benefited by the wet season, but potatoes were nearly a failure, and corn was considerably damaged on many fields. Pastures continued to supply good feed throughout the season, so that the year proved to be a favorable one for the dairy farmer. From the table of rainfall observations reported from 22 localities in the State, for the six months (May 1 to October 31), it will be noticed that the average rainfall for the State was quite heavy for each month except June.

The average temperatures for January and February were slightly below the normal for those months as recorded at Storrs, the weather for February being especially cold. The temperature for March was about normal while April and May were cool and wet. Frosts were not very damaging, yet the generally cool weather checked the growth of most of the crops. The last killing frost occurred May 6, although the damage was not very general. June was warm and generally favorable for all crops. The temperature for July was above the normal, while that in August was about the average for the month. Frost held off well in the fall, the first to do much damage occurring September 26, thus giving a growing season of 142 days from the last killing frost in the spring. October and November were generally mild and especially favorable for harvesting crops and for fall plowing.

The following general review of the crop season, given in the annual summary of the Climate and Crop Service of the United States Weather Bureau for New England, although pertaining to the whole section, will, in the main, apply very well to the conditions in Connecticut.

REVIEW OF THE CROP SEASON.

The crop season of 1901 opened fully as early as usual and under very favorable conditions. During the third decade of March the snow disappeared and the frost left the ground over the southern half of the section, but in the northern portion there was much snow at the close of the month, ranging from broken patches in the fields to four feet in the wooded lands and the mountains. The large amount of precipitation during March, together with the melting of the accumulated snow, furnished an abundance of water, and the soil was in excellent condition at the opening of the crop season as regarded moisture. The reports of the crop correspondents showed that winter grain and grass had wintered well, and that fruit buds were in a healthy condition. By the close of March plowing and gardening were in operation in Rhode Island and southern Connecticut. Growing crops, grass and winter grain, made good progress during April, and, at the close of the month, pastures and meadow fields were green and vigorous even in the most northern sections of the district, and an abundant hay crop seemed assured. Much early gardening was done during this month in all parts of the New England States. But owing to the wet condition of the soil, especially in the low lands, spring seeding and general planting were delayed and were backward. The season was unfavorable to maple sugar and this crop was nearly a failure, the even temperature and the absence of sunshine being unfavorable to a free flowing of the sugar sap. Excepting grass and winter grain, crops were considered backward at the close of April. May, generally speaking, was not a good month for farming interests. There

was an excess of rainfall and a marked deficiency in the amount of sunshine. The soil was too wet and cold for growing crops and for the germination of planted seed. Grass continued in a promising condition, but for all other crops the season was reported late, from ten days to a fortnight behind the average. There was little improvement till after the 10th of June. The warm, sunny weather, which prevailed after that date, was most beneficial to all growing crops; planting progressed to a finish and hoeing and general cultivation were carried on with much success. At the end of June potatoes were from a week to ten days later than for the average season but promising; a large crop of grass was ready for the harvest; fruit excellent except apples, which gave every indication of a light yield; vegetables and garden products, in general, were making rapid growth, and many of them ready for the market. About all crops progressed favorably through July; corn and tobacco were especially promising crops; potatoes improved, but were generally estimated as below the average; the hay crop was harvested under very favorable conditions, and the yield was one of the largest for a number of years. The weather during August was most favorable to growing and maturing crops and to harvesting. Potatoes continued to improve and were more promising than earlier in the season. With slight exceptions the apple crop was reported a failure, the yield being the smallest for many years and the fruit of inferior quality. The season closed with September and October, and under auspicious conditions, the weather being favorable to the harvesting of all farm products, to fall plowing and to seeding. The concluding reports of the crop correspondents showed bountiful yields of corn, tobacco and hay; vegetables plentiful and good, although potatoes were below the average yield. Pasturage remained good well into November and stock went to the barn in fine condition for the winter. Viewed as a whole, the crop season and its outcome were eminently satisfactory to the farmers.

TABLE 136.

Rainfall during six months ending October 31, 1901.

LOCALITY.	OBSERVER.	INCHES PER MONTH.						Total.
		May.	June.	July.	August.	September.	October.	
Canton, - -	G. J. Case, - -	7.21	1.24	3.03	6.42	5.76	4.66	28.32
Clark's Falls, -	E. D. Chapman, -	6.14	1.51	4.70	2.48	—	—	—
Colchester, - -	S. P. Willard, -	7.29	2.33	6.64	7.83	5.47	2.82	32.38
Cream Hill, - -	C. L. Gold, -	6.90	1.69	4.57	6.97	4.52	4.37	29.02
Falls Village, -	M. H. Dean, -	6.07	1.84	4.39	9.04	4.21	3.97	29.52
Hartford, - -	H. H. Moore, -	7.20	0.86	3.23	7.57	5.04	3.60	27.50
Hawleyville, - -	E. N. Hawley, -	7.23	1.01	5.64	7.81	5.02	4.14	30.85
Lebanon, - -	E. A. Hoxie, -	7.23	1.60	6.72	7.46	3.37	2.15	28.53
Madison, - -	J. D. Kelsey, -	6.39	0.42	3.62	5.39	9.02	2.53	27.27
Middletown, - -	A. P. Bryant, -	8.05	0.84	4.86	7.78	6.57	4.79	32.89
New Haven, -	Weather Bureau,	6.38	0.25	4.40	6.92	5.70	2.95	26.60
New London, -	J. R. May, - -	4.75	1.20	2.38	1.35	4.92	1.60	16.20
Norfolk, - -	G. O. Stoddard, -	3.98	1.90	3.33	7.40	3.40	4.40	24.41
N. Grosvenor Dale,	Grosvenor D. Co.,	5.12	1.50	4.32	5.01	4.17	3.36	23.48
Norwalk, - -	G. C. Comstock, -	8.34	1.29	4.89	8.97	3.08	3.48	30.05
Southington, -	L. Andrews, -	7.00	0.50	6.30	5.95	6.60	3.55	29.90
South Manchester,	K. B. Loomis, -	5.45	1.06	6.58	9.53	5.51	3.40	31.53
South Windsor, -	J. N. Fitts, -	5.12	0.72	4.12	6.90	5.61	3.15	25.62
Storrs, - - -	Exp't Station, -	6.30	1.96	5.54	7.58	4.33	1.97	27.68
Voluntown, - -	Rev. E. Dewhurst,	6.08	2.33	3.96	3.33	4.91	1.85	22.46
Waterbury, - -	N. J. Welton, -	8.08	0.65	4.44	9.37	6.25	4.32	33.11
West Simsbury, -	S. T. Stockwell, -	7.15	1.60	2.54	5.82	5.16	4.27	26.54
Average, - -	—	6.52	1.29	4.55	6.68	5.17	3.87	27.80

TABLE 137.

Meteorological summary for 1901.

[Observations made at Storrs by the Station.]

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.	Total.
Highest barometer,	30.77	30.35	30.37	30.53	30.40	30.66	30.31	30.30	30.56	30.69	30.42	30.56	30.49	—
Lowest barometer,	29.09	29.38	29.26	29.34	29.57	29.69	29.77	29.84	29.62	29.57	29.33	29.48	29.50	—
Mean barometer,	30.00	29.83	29.92	29.99	29.93	30.03	29.66	30.08	30.09	30.18	29.99	30.09	29.98	—
Highest temperature,	46	41	54	81	80	92	95	83	87	76	59	63	—	—
Lowest temperature,	−8	3	4	31	34	44	51	54	38	30	8	0	—	—
Mean temperature,	25	19	33	45	54	67	71	66	62	50	33	29	—	—
Relative humidity,	—	—	—	83	83	80	82	84	70	78	—	—	—	—
Total precipitation, inches,	8.50	1.05	7.18	9.51	6.30	1.96	5.54	7.58	4.33	1.97	3.04	9.55	—	66.51
No. of days with .01 inch or more precipitation,	11	5	13	16	16	9	14	10	9	7	9	12	—	131
No. of clear days,	5	9	4	5	5	10	6	8	14	15	9	6	—	96
No. of days partly cloudy,	13	16	9	4	13	14	15	9	8	10	8	15	—	134
No. cloudy days,	13	3	18	21	13	6	10	14	8	5	13	10	—	134

INDEX.

PUBLICATIONS OF THE STATION.

The publications of the Station will be mailed free to all citizens of Connecticut, and to Granges, Farmers' Clubs, and other agricultural organizations, that ask for them, and so far as circumstances permit, to those who apply from other states.

To meet requests constantly received for information regarding the publications, a supplement to the Report for 1900 has been published, giving a list of the Annual Reports, Bulletins, and Reprints issued by the Station since its organization. The list includes that portion of the table of contents of each Report which gives the titles of the articles contained in it; the number and title of each Bulletin, and the title of each Reprint with the number of the Report from which it is taken. In addition to these, the titles of several Reprints from the Reports of the Connecticut Board of Agriculture concerning the work of the Station are also given. In the list those publications of which copies are no longer available for distribution are appropriately marked.

Requests for the above mentioned list, or for any of the publications of the Station should be addressed to

STORRS AGRICULTURAL

EXPERIMENT STATION,

TOLLAND COUNTY. STORRS, CONN.